FAO - Food and Agriculture Organisation of the United Nation
Scientific Advisory Committee of the GFCM
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Directorate for Fisheries of the Italian Ministry for Agriculture and Forest Policy

PROCEEDING OF THE WORKSHOP ON REFERENCE POINTS

held in Rome on April 20-21, 2004

This is a draft version of the communications presented during the workshop. The manuscripts are currently under referees revision process before acceptance for publication.
Not to be cited without prior reference to the authors.

The most part of the articles included in the present book are a re-elaboration, provided by the authors, of the communications presented at the workshop on Reference Points held in Rome on April 20-21, 2004 on behalf of the SAC-GFCM jointly with the Directorate for Fisheries of the Italian Ministry for Agriculture and Forest Policy.
Some articles are from the presentations given at the workshop on Reference Points organized in Rome on January 28-29, 2004 by the Directorate for Fisheries of the Italian Ministry for Agriculture and Forest Policy.

Scientific Advisory Committee of the GFCM
Sub-Committee Stock Assessment

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Workshop on Reference Points

Palazzo Altemps, Via de Gigli d'Oro n° 21, Roma
April 20-21, 2004

The workshop was attended by 60 participants. Besides the introducing talk, 14 communications were presented by researchers and 1 communication was presented by the fishermen associations.

The approaches illustrated in the communications could be subdivided as follows:

a) classical population dynamics modelling (single species), n°7 presentations;
b) empirical indicators of population (single and multispecies), n°4 presentations;
c) multispecies and ecosystem indicators; n°2 presentations;
d) ecosystem and composite indicators; n°1 presentation

One communication didn't deal with RPs issue but was aimed at suggesting a twin tools for fishing management.
The communication of the fishermen associations mainly underlined the needing of understandable RPs and the incorporation of social and economical issues in the advices.

The communications will be published on the journal Biologia Marina Mediterranea.

Reference points workshop – discussion session

The session was chaired by Giuseppe Lembo (Coordinator of the workshop), Alain Bonzon (GFCM secretary), Corrado Piccinetti (SAC Chairman), Riccardo Rigillo (Italian Directorate of Fisheries) and Matthew Camilleri acting as reporter. The former thanked the authors of the presentations made during the workshop and opened the discussion by putting forward a few pertinent questions:

1. Which are the indices and RP currently applied to Mediterranean fisheries, and which others have never been applied and why?
2. What level of reliability have the indices and RP used in the Mediterranean? How can this reliability be improved?
3. Has any multispecies index or MSRP ever been applied to the Mediterranean? If so, in what circumstances?
4. EAF is a main issue. There are some papers published on this topic but, have had any impact on assessment?

5. How can use common information from different areas or gathered with different methods to standardize indices and reference points?
6.- On the light of the previous items, which kind of recommendation, regarding indices and reference points, can be addressed to the SAC-GFCM?
There was consensus that reference points in the Mediterranean have so far been applied to stock assessment exercises and were not used within a management framework. It was noted that most of the papers presented during the workshop focused on biological reference points which needed to be assessed, on the basis of their characteristics, for their feasibility and usefulness in the precautionary approach. Namely the indicators should be characterised by the following desirable features:

a) easy compilation and processing procedures;
b) minimization of basic assumptions;
c) reliable performance with respect to interactions between fishery, environment and resources;
d) applicability to different scenarios;
e) comprehensibility for the stakeholders;
f) easy integration and comparison among indicators coming from different sources.

As far as the group was aware, mainly monospecific models have been used in the Mediterranean and problems are being encountered to translate the EAF and related models to management interventions.

On exploring the overall scenario, the group stated that the establishing of reference points should be an activity carried out by scientists but should be understood by fishers and other stakeholders. It was suggested that they should have three uses: (a) monitoring (b) management implementation (c) determination of state of stock / restoration. It was also noted that demersal stocks are more vulnerable and need focused attention with defined recovery plans which set target values or reference points.

It was proposed that initially limit reference points should be established in order to implement management interventions and target reference points could be considered at a later stage. The group believed that data should be analyzed on a large scale basis in order to smoothen out variability and that an integrated multispecies approach should be the preferred option.

Life expectancy was identified by some as a robust indicator of survival which is a tool to assess the well-being of the stock, as well as to simulate the effects of different management strategies. Total mortality was also identified as a suitable indicator to set a limit reference point and it was noted that trawl surveys are useful in this regard, since they provide interannual fluctuations in this parameter. It was also suggested that CPUE is itself a simple and reliable indicator.

The group discussed the often met unreliability of commercial catch data and the quality of data collected through direct and indirect methods, which depend on the sampling strategy employed. The issue of the reliability of indicators depends on what they are used for. Since there have been no applications of fisheries control rules using indicators and RPs, there is no history of experience to study. Caution was expressed in

the use of specific modelling frameworks to generate RPs before a broader view of the situation is obtained. A method of examining a large number of indicators together is proposed as a preparatory approach before setting up a modelling framework.
Concern was also expressed with the use of “steady state” assumptions in modelling, such as Ecopath or Y/R models, there is a lot to be said for using empirical indicators that are easily understood by managers and fishermen.

The group stated that the uncertainty of reference points could be reduced through collaboration and sharing of data and experiences, as well as calibration of data. It added that whilst the indices presented at the workshop should be used as a foundation for future work on this subject, data and information originating from landings, direct methods and simulation should be retained and an effort should be made to integrate socio-economic aspects. It was emphasized that in using this approach, researchers must keep in mind that the ultimate goal is to manage fisheries and not to focus singly on biological aspects of stocks, whose status depends on several other biotic and abiotic influencing factors. Furthermore, the use of a “traffic light approach” for assembling different indicators into a baseline of information for management decision was suggested before going deeply into modelling on a narrow range of assumptions.

In trying to reach a conclusion, the group suggested that in addition to indicators and reference points for single different stocks, specific indicators for each fishery or Operational Unit should be identified (poly-indicator system), which would be understood by all stakeholders. Moreover, it was proposed that each reference point should undergo a robustness and / or sensitivity test before being applied.

The group pointed out that indicators and reference points could be obtained through catch assessment surveys and direct methods to get information mainly on the catch size spectrum (individual species and all species), mortality rates (e.g. Z_{med}, Z_{MBP}, $F_{0.1}$), recruit and spawner indices (e.g. R/S, SSB/SSB_0, SSB/B, B/R), abundance indices, condition factors and estimates of the area extend of the stocks surveyed. Further indicators could be derived by examining historical data sources for past changes in overall ecosystem indicators (e.g. pelagic/demersal ratios, piscivore/planktivore ratios, PPR-TL_{catch}), diversity indices as overall indicators of ecosystem change (e.g. BOI index), change in basic ecosystem productivity and other environmental variables such as meteorological data.

Finally, the working group strongly suggested that the SAC-GFCM should continue to promote the reference point issue as a priority research area in order to define clear management goals at regional level as soon as possible.

INDEX OF THE PAPERS

SELECTION OF POSSIBLE INDICATORS OF SUSTAINABLE YIELD FROM TOTAL MORTALITY RATES FOR THE RED MULLET, *MULLUS BARBATUS* LINNAEUS, 1758, IN THE GFCM GEOGRAPHIC SUB-AREA 9 (EASTERN LIGURIAN-CENTRAL TYRRHENIAN SEAS).

SELEZIONE DI TASSI DI MORTALITA' TOTALE COME POSSIBILI INDICATORI PER IL RENDIMENTO SOSTENIBILE DELLA TRIGLIA DI FANGO MULLUS BARBATUS *LINNAEUS, 1758, NELLA SUB-AREA GFCM 9 (MAR LIGURE ORIENTALE – TIRRENO CENTRALE)*

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Key-words red mullet, reference points, stock assessment, Western Mediterranean

Abstract

Biological Reference Points based on total mortality rates, were tested for the assessment of the status of Mullus barbatus *(Pisces, Osteychtyes) stock in the GFCM Geographic Sub-area 9, western Mediterranean. The suitability of each one of the chosen BRP for the assessment of the level of exploitation of the species is briefly discussed.*

Introduction

The precautionary approach for fisheries, as specified by the FAO Code of Conduct (FAO, 1995a), is related to the conservation, management and exploitation of the living resources and to the preservation of the aquatic environment. For the implementation of the precautionary approach, the administrators need to improve decision-making for resources conservation and management. These decisions should be based on sound scientific evidence allowing the definition of stock specific reference points, as well as on actions to be taken if they are exceed (FAO, 1995a).

Reference points can be defined as conventional values of the state of a fishery or a population that are considered the desirable objective to be reached (*target reference points*) or an undesirable state of the fishery which needs to be avoided (*threshold* or *limit reference points*).

An increasing frequency of use of biological reference points to define the state of some fisheries of demersal stocks has been observed in recent years. The criteria for the selection of the more suitable reference points for the management of a certain fishery are mainly done by identifying whose are compatible with the current knowledge of the resources, with their biological characteristics and with the employed fishing strategies. There is a general agreement that the reference points that up to the present time were more frequently used (F_{max}, $F_{(Fmsy=M)}$ and $F_{0.1}$) are not precautionary (Caddy & Csirke, 1983, Clark, 1991, Mace & Sissenwine, 1993, Caddy & Mahon, 1995, Die & Caddy, 1997). This is because they are extremely dependent to both, the specific stock biological characteristics (reproductive capacity, resilience) and characteristics of the fisheries exploiting the stock. The models are very sensible to many variables, as the age at recruitment to the gear, the age at maturity, the natural mortality rates and other biological parameters of each species.

Even though the fisheries are conceived for the achievement of socio-economic benefits, it is necessary to consider the sustainability of the activity through the conservation of the production potential of the exploited resources. In consequence, an important management goal is the choice of measurable indices of the level of exploitation that provide a good compromise between the best attainable yields or revenues and a good probability of avoiding stock collapse. This is achieved with the best scientific available information and the implementation of improved techniques for dealing with risk and uncertainty (Caddy & Mahon, 1995). Uncertainty is an intrinsic aspect of any fishery system. It concerns the measurement of size and productivity of the stocks, the chosen reference points, the definition of levels and distribution of fishing mortality, the impact of fishing on by-catch, as well as the environmental and socio-economic conditions.

In the present paper, some Biological Reference Points (BRP) based on total mortality rates, were used in order to assess the status of *Mullus barbatus* stock in the GFCM Geographic Sub-area 9, Western Mediterranean. The appropriateness of each one of the chosen BRP for the assessment of the level of exploitation and risk of collapse of the species is briefly discussed.

The *M. barbatus* fisheries in Geographic Sub-Area 9

The red mullet, *Mullus barbatus,* is one of the most important commercial fishery resources of the Geographic Sub Area 9 that extends from Ligurian to Central Tyrrhenian Sea (Fig.1). The species is mainly caught by bottom trawlers in the depth range 15-100m.

In this area, *M. barbatus* is an important species of the demersal species assemblages of the continental shelf (Biagi *et al.*, 2002) and one of the most important targets of the demersal fishery. The commercial landings are therefore constituted by an important fraction of by catch, which species composition may change along the year, due to the relative abundance and availability of the single species and to the commercial choices of the fishermen that change their exploitation strategies (Abella and Serena, 1995; Abella *et al.*, 2001).

M. barbatus is also caught by the small scale fisheries, mainly with trammel nets, but the amount of artisanal catches is modest if compared with that produced by trawling.

In the last 13 years, a general decrease in the consistency of the fishing fleets operating in the GSA9 and targeting demersal species, that include red mullet, has been observed. This decrease has been particularly important for the Porto Santo Stefano fleet (about 50% of reduction of the number of vessels) and for that of Viareggio (about 30%) (Fig 2). It is likely that this reduction has produced a consequent decrease in the fishing effort directed to *M. barbatus*.

Landings of red mullet are characterised by a clear seasonality (Fig 3), with a peak at the beginning of autumn, as soon as the recruitment is already completed, with young individuals concentrated near the coast. Trawling close to the shore, within 3 miles from the coast (or under 50m depth along the Ligurian coast) is forbidden all year round. A further reduction in the capture of juveniles has been attempted through the seasonal fishing ban for trawling (30-45 days in late summer-early autumn), that was enforced in several years.

Red mullet catch rates (landings per unit of effort) have shown an increase in the last years in almost all the ports of the GSA9. The same trend is observed for the annual standing stock biomass estimates with data proceeding from trawl surveys (Fig 4).

The *M. barbatus* stock status has been assessed in the last years for some zones within the GSA9 (Orsi Relini & Arnaldi, 1986; De Ranieri *et al*., 1994; Demestre *et al*., 1997; Voliani *et al*., 1998; Ardizzone, 1998; Abella *et al*., 1999; Zamboni *et al*., 2000). Yield-per-Recruit and Spawning-per-recruit analyses were performed as well as Surplus Production Composite Models. However, no assessments for the whole GSA9 were performed up to now.

Material and methods

Data proceed from trawl surveys performed in the GFCM Geographic SubArea 9 (CGPM, 2001) (from Ventimiglia to Garigliano River, comprising Ligurian Sea, Northern Tyrrhenian Sea and Central Tyrrhenian Sea, (Fig. 5) in the period 1985-2003.

Italian GRUND surveys (Relini 1985,1998) covered the whole GSA9 with a common sampling protocol, but most of the times using different vessels and fishing gears for the different sub-zones. Information proceeding from the mentioned scientific cruises was used here mostly for a better knowledge of biological aspects of the species.

MEDITS EU funded surveys (Bertrand *et al*., 1997) were performed utilising vessels with similar structural characteristics of engine power and gross tonnage and with an identical fishing gear and sampling protocol. In consequence, information derived from MEDITS surveys was also suitable for the comparison of catch rates.

The reference points tested in this paper derive from the most common families of approaches for stock assessment, namely: biomass dynamic models, dynamic pool models and those based on the likely relationships between spawners and recruits.

The first approach used is based on biomass dynamic models.

Production Models or Biomass Dynamic Models describe production as a function of biomass. Traditionally, these approaches employ data proceeding from the commercial fleets. In the Mediterranean Sea, the information required for the utilisation of traditional versions of these approaches is only available for a reduced number of ports or fisheries. On the other hand, for a large number of areas, data proceeding from trawl surveys are available, especially since 1994 when the MEDITS programme started. Fisheries independent data, as those proceeding from trawl-surveys do not allow collecting information neither on fishing effort nor on catch. However, there is the possibility to apply a variant of production models, the so-called *composite models* (Munro, 1979) that allows the use of information derived from trawl surveys performed with standard procedures in different areas assumed to have the same ecological characteristics but exploited with different rates. Coverage includes the main red mullet fishing grounds exploited in the Geographic Sub-Area 9.

Considering the absence of effort data for each sub-zone and fishery, estimates of the total mortality rate Z were used as a direct index of current fishing effort. Z was estimated through the calculation of survival rates of each single cohort for each sub-zone in two successive periods. Survey catch rates (kg/h) corresponding to each sub-zone were used as an index of abundance at the current level of exploitation rate.

In order to increase the contrast among data, a couple of values of Z and cpue estimated for a zone of the Southern Tyrrhenian Sea (Castellammare Gulf, Sicily, identified as

Sub-zone 11 in the Fig. 5 was also included. In the mentioned area, a fishing ban for trawling do exist since 1990 (Pipitone *et al.*, 1996) and only a negligible amount of individuals of red mullet are caught by the artisanal fishery. Hence, it is likely that the estimates of catch/hour and Z for *M. barbatus* of the mentioned area do approximate the rates of a virgin population.

The use of the model with the empirical data allowed the estimation of Z corresponding to the Maximum Biological Production (MBP) proposed by Caddy and Csirke(1983). MBP includes all the production removed by both, fishery and natural mortality.

The second approach tested for red mullet in the GSA9 belongs to the Dynamic Pool Models group. In this paper, a Thompson & Bell like model (Thompson & Bell, 1934) was constructed. Common biological parameters (considered representative for the species in the sub-area were used (Voliani *et al.*, 1998; Sanchez *et al.*, 1995; De Ranieri, 1999, Tab. 1). A vector of natural mortality, with a declining value of M with the increase in size, was included; the assumption of M varying with size was necessary considering that the species starts to be exploited at a very young age. It is generally accepted that young small-sized individuals are characterised by higher natural mortality rates than those of adults. The M vector introduced in the model was constructed following the Caddy model (1991). The values of the parameters A and B of the mentioned model were defined based on the available information for different phases of life of the species that also includes estimates of M of pre-recruits (Voliani *et al.*, 1998). An F vector, which is assumed to represent the distribution of fishing mortality by size in the commercial catch, was used.

With this simulation approach, the changes in Y/R and in the rate current Spawning Stock Biomass/virgin Spawning Stock Biomass (SSB/SSBo) due to changes of fishing mortality, were estimated. A reference threshold value of 0.35 was used for the SSB/SSBo rate, as recommended in literature for species with life history characteristics similar to those of the red mullet (Clark, 1991, Mace & Sissenwine, 1993)

The third approach used here is based on the Stock/Recruitment relationship and the concept of F_{med} (ICES, 1984, 1985), successively developed by Sissenwine and Shepherd (1987). It allows the identification of the level of mortality (in this case total mortality Z) that should guarantee adequate and sustainable yields. Z_{crash} and Z_{med} linked to the replacement of the spawning biomass were estimated. Z_{med} corresponds to the line representing an average survival, S/R=1, at which stock replaces itself. At this level of Z, recruitment overbalances, in about half of the years, the losses due to mortality. Z_{crash} is the level of Z corresponding to the intersection of the yield and fishing mortality relationship with the Z-axis estimated by a Z-based production model. If fishing is maintained at the Z_{med} rate, it is assumed that the stock will be sustained. Z_{med} is considered a limit reference point. Also in this case, in order to be able to use data that reflects contrasting enough situations as regards the exploitation rates, yearly estimates of spawners and recruits from different sub-zones of the GSA9 were considered independently and not merged as a single couple of S and R for the whole GSA.

The fourth tested approach is based on the Beverton and Holt (1957) equation that allows the estimation of Z if the size of first capture L_C, the average length of the entire catch $\overline{L}$ and the von Bertalanffy growth parameters *K* and L_∞ are known.

Die and Caddy (1997) defined a new reference point, Z*, aimed at a rough assessment of the likely effects of fishing on the spawning stock and successive future recruitment. For the utilisation of this index, the knowledge of the size at first maturity, L_m, and the size at first capture L_c are needed. The basic idea is that when the mean size in the catch is longer than the size at maturity, on average, an individual fish will have spawned at least once before it is caught.

Based on the Beverton & Holt (1957) equation:

$$Z = \frac{(L_\infty - \overline{L})K}{(\overline{L} - L_c)}$$

By incorporating the inequality $\overline{L} < L_c$

and by substituting L_c by L_m,

the following inequality that furnishes an upper limit reference point based on Z, is obtained:

$$Z* < \frac{(L_\infty - L_m)K}{(L_m - L_c)}$$

Considering the differences of growth and maturity parameters between males and females, the estimation of Z* was performed separately by sex and successively pooled taking into account the sex ratio of the population.

Results

For the whole GSA9, referring to the current value of the total mortality Z, an average rate of 2.72 was estimated.

From the Composite Model, a value of Z corresponding to the Maximum Biological Production of 2.25 was estimated (Fig. 5). The single values of Z obtained in the different sub-zones, compared with Z_{MBP}, suggest different exploitation rates for the grounds present inside the GSA9: while the sub-zones 1, 2, 4 and 5 resulted overexploited, the current Z value corresponding to the area 3 indicates an underexploited status. Data proceeding from sub-zone 6 didn't allow a reliable estimation of the variables needed for the analysis. The current value of Z estimated for the whole GSA is positioned beyond the Z_{MBP}.

Results from the Y/R and SSB/R analyses (Fig 6) suggest, for the current level of F (average value for the whole GSA9), that at this exploitation rate a Y/R of about 20% lower than the maximum is obtained. The BRP based on the current SSB/SSBo rate (assuming a threshold value of 0.35), suggests that a reduction of the current level of effort of about 25% is needed to reach the value corresponding to the above-defined threshold, that is considered more suitable to guarantee the self-renewal of the stock.

A value of 3.0 was estimated for Z* that results higher than the current value estimated for the whole GSA. An analysis of the sensitivity of each input parameter used for the estimation of Z* was performed. The results are very sensible to light changes in the input parameters, especially for Lm, as is shown in Fig.7.

The Sissenwine & Shepherd (1997) approach allowed the estimation of a Z_{med} value of 3.43. The actual value of Z for the whole GSA9 is decisively lower than the obtained value of this reference point for *M. barbatus* in the area.

The replacement lines corresponding to the different BRP considered in this study: Z_{med}, Z_{crash}, Z*,Z_{MBP}, $Z_{SSB/SSBo}$=0.35 are shown in Fig. 8. The last two RP's give a less optimistic picture of the exploitation status of the species, suggesting the need of a reduction of the current Z while Z* is positioned close to Z_{med}.

Data allowed the construction of a proper model for the Stock/Recruitment relationship, even if the Sissenwine and Shepherd approach does not need of a formalisation of such relationship. The Ricker model explains fairly well the distribution of the data (level of recruitment expected at different levels of abundance of the adult stock).

Table 2 shows the current value of Z and those corresponding to the different reference points utilised in this exercise. The same table also shows:

-Y/R and SSB/SSBo resulting for the current level of Z;

-the Y/R and SSB/SSBo corresponding at each considered BRP after reaching the new equilibrium;

-the changes in F necessary to drive the current Z value to the level defined by each RP.

The comparison of each BRP with the current value of Z furnishes rather different pictures of the current exploitation status of the stock. In fact, the indication proceeding from the reference values Z_{MBP}=2.25 and $Z_{SSB/SSBo=0.35}$=2.19 suggests the necessity of a strong reduction of the current Z. On the other hand, the values of Z* and especially that of Z_{med} do not indicate the need of any reduction of the current Z. However, at these levels of exploitation, reductions of about 4 and 11% in Y/R and a drop of the surviving fraction of spawners related to the maximum spawning potential to 0.26 and 0.23 are respectively expected. These values are decisively lower than the chosen threshold of 0.35.

Discussion and Conclusion

The use of different reference points for fish resource management is advisable, especially in areas like the Mediterranean, considering the uncertainties as regards the fishery system and "the need to take action with incomplete knowledge", as stated in the FAO expert consultation on the Precautionary Approach to Fisheries Management (FAO, 1995b). In fact, when the signals derived from the use of different reference points are consistent, there are more probabilities that the assessment and consequent advice are correct.

Considering that he reference points that were in the past more frequently used for the Mediterranean fisheries as F_{max}, $F_{(Fmsy=M}$ and $F_{0.1}$ are not precautionary, this fact have driven to the search of alternative reference points based on mortality rates or minimum biomass thresholds associated with the risk of stock collapse. The choice among the large amount of reference points proposed in literature is however restricted to those compatible with the current knowledge of the resources, with their biological characteristics and with the employed fishing strategies.

The use, in the present paper, of a series of approaches and reference points considered precautionary and suitable for the stock assessment and management of Mediterranean fisheries did not furnish the same photograph of the exploitation status of the stock of *M. barbatus* in the Geographic Sub-area 9. Several factors are assumed to have contributed to these contrasting results.

The exploitation status that results from the application of the composite model with Z as a direct index of effort are in agreement with what we know about the fishing pressure exerted in the single sub-zones of the GSA9. If some general recommendation based on this reference point has to be furnished for the whole GSA9, considering that almost all the different sub-zones are clearly beyond the Z_{MBP}, we should say that the Z values are in general too high and that it should be necessary to reduce Z. The reduction of Z can be obtained through the reduction of fishing effort or fleet capacity. However, it is likely that such measures will punish the fishing fleet that exploits only moderately the sub-zone 3.

Reliable results from production models are only obtained when enough contrasting data are available (Hilborn and Walters, 1992). In this case, the composite model uses data that reflect the changes in demographic structure and biomass that occurred in different sub-zones characterised by quite different exploitation rates. The use of a composite model also allowed to avoid the problems related to the assumption of equilibrium, a problem that is necessary to deal with, when using time series of catch and effort. Hilborn and Walters (1992) state that probably the only type of equilibrium analysis that appears suitable when we are working with production models involves spatial contrast in fishing effort.

The Z_{MBP} approach is considered precautionary because it is always lower than Z_{MSY} (Caddy and Csirke, 1983). The requested data are very simple to obtain and no strong assumptions are needed. In fact, it works as a "black box" and do not need of explicit modelisation neither of recruitment, growth nor natural mortality processes.

Die and Caddy (1997) stated that the approach is also consonant with the growing availability of estimates of total mortality rate from length-based methods that occurs in the Mediterranean.

In consequence, Z_{MBP} can be considered one of the more highly rated candidates as BRP for areas like the Mediterranean considering the limited knowledge of the species biology and fisheries. Die and Caddy (1997) showed that it is difficult to produce excessively high fishing mortalities using the Z_{MBP} approach. Moreover, when the stock is at its maximum productive capacity (B_{MBP}) the risk of ecological perturbation should be minimised.

The approach based on the Stock/Recruitment relationship furnishes a Z_{med} value quite high and suggests that the stock be in a fairly good exploitation status. The estimated value for Z_{med} results in a percent of the current spawning stock biomass related to the maximum spawning potential of 23%.

Norris (1991) stated that when density dependent phenomena occur, each level of fishing effort has an associated equilibrium stock abundance. In these cases, the F_{rep} estimated through the use of a Sissenwine and Shepherd approach is highly dependent on the range of stock abundances for which spawner-recruit data are available. Also in this case, the high value of Z_{med} that was estimated might be conditioned by the predominance in the available data of couples of spawning stock and new recruits that are representative of the high levels of fishing pressure at which the species is exposed in most of the considered sub-zones.

Moreover, it is necessary to consider that by only controlling the value of Z it is although possible to drive the stock to an undesired status. According to Hayes(2000), two different fishing mortality patterns (due to different combinations of fishing intensity and age of first capture) may produce the same maximum spawning potential or viceversa, with the same fishing or total mortality rate but changing the size of first capture, the resulting maximum spawning potential can be quite different. In consequence, it should be necessary to control both variables in order to avoid the risk of recruitment overfishing.

The analysis performed with a dynamic pool model suggest that a reduction of fishing effort should be necessary in order to drive the stock to a safer situation regarding its current level of Spawning Biomass. This reduction, estimated of about 25%, is likely to drive the SSB/SSBo rate to the reference value of 0.35 and to an increase of about 20% in Y/R. This assessment is however conditioned by several assumptions especially regarding the natural mortality vector introduced in the model. In the case a constant (and low) value of M is introduced, a decisively worse picture for the species stock status is obtained.

It is supposed that the use of reference points as Z*, especially through the monitoring of the Z level in the case of developing fisheries, should be very useful for the reduction of risk of recruitment overfishing (Die and Caddy, 1997; Zamboni *et al.* 1999). By keeping the current value of Z below this reference value, each individual on average will be able to spawn at least once on its life. It is however not proved that this reference point is suitable for species like *M. barbatus,* characterised by a short lifespan and low age at first maturity (about 1 year). Most of the individuals of the multispecific the fishery including *M. barbatus* among the target species are caught before they reach its size/age of maturity and it is likely that this exploitation pattern will not change in the future. Furthermore, any management plan or technological measure based on this BRP and aimed at an increase of the size of first capture could be very difficult to apply. Moreover, it is in general very difficult to define the real size of first maturity. The fitting of an ogive of probability of maturity by size does not furnish the mean size at which the species massively spawn, but a size that is systematically much lower than the size that, on average, the individuals will reach when they will spawn for the first time (Voliani *et al.,* 1998).

From the reference points tested here for *M. barbatus*, Z_{MBP} derived from a Composite Model with Z as a direct index of fishing effort seems in the present circumstances one of the more suitable for the stock assessment of the mentioned species in the Mediterranean context. This approach is one of the less data-requiring and with the advantage that always furnish sustainable fishing rates.

Another approach that does not need of a big amount of data, hypotheses nor models, is the Sissenwine and Shepherd (1987) method. The achievement of reliable results with the mentioned approach, however, is strongly conditioned by the range of stock abundances for which spawner-recruit data are available.

The reference point based on the choice of a threshold level of F that reduces the spawning biomass to a certain percentage of its pristine biomass (in our case 35%) derive from simulations that suggest that if fishing is maintained at this rate, yields will be at least 75% of the MSY and the self-renewal of the stock should be guaranteed. In the Mediterranean context, considering a general lacking of knowledge on the population dynamics and fisheries of many stocks, approaches like that, that are less information-demanding, should have broad potential in fisheries such those of the mentioned area. There are however some problems that have to be solved before their utilisation.

For the estimation of the surviving fraction of the spawning biomass at the current level of F, we have to introduce in the model a series of assumptions, many times not completely supported by scientific evidence, in particular, regarding the vector of natural mortality by age. It has been observed that these models are very sensible to changes in this input parameter and hence, results may be quite different if an alternative hypothesis is introduced. According to the comparative study of Caddy and

Mahon (1995), %SPR was found to be positively correlated with natural mortality and negatively with some indices of size. In this case, fast growing short-living species should require higher percentages of survival fraction of the spawning biomass to guarantee an adequate stock replacement.

As regards to the use of Z*, there exist some problems for its utilisation for stock assessment in fisheries like those Mediterranean. They are mainly related to the use in the fisheries of the area of low-selective small mesh-size, to the multispecific characteristics of the fisheries and to the need to assume, as implicit in the original Beverton & Holt equation, a similar fishing mortality rate for all the individuals over the size of first capture. Moreover, the model was demonstrated to be very sensible to the input value of size at first maturity, especially if low values are introduced.

When a RP has to be chosen, an important aspect that has to be considered is the possibility to translate in an easy way the results obtained through the utilisation of the conventional values chosen as reference points (in this case total mortality rates) in clear advice for management purposes, expressed in practical and measurable bounds for fishing effort, fishing capacity, catches, etc. Z_{MBP} estimated through the use of a Composite Models is again, the more suitable for an easy implementation of advice derived from the assessments. In fact, it is not very difficult to obtain, for each considered sub-zone, information on the number of fishing vessels targeting certain species or to the number of trips per year. Z estimates for each sub-area can be compared, as performed by Abella *et al.*(1999), with information on the fishing effort exerted on each one of the corresponding sub-areas and thus defining the level of fishing pressure corresponding with Z_{MBP}.

As a general and final comment, we can state that for the assessment of the status of the stock that apply for the whole Geographic Sub-Areas, some objective difficulties can exist. This is mainly due to the fact that not always the boundaries of these GSA's coincide with the "natural" limits of the exploited stocks and these arbitrary divisions may create difficulties to gather (and to analyse) in a proper way the information proceeding from different sub-zones within each GSA. In fact, these sub-zones are exploited with different rates and patterns, depending on the different consistency (and behaviour) of the fishing fleets targeting demersal resources.

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Fig. 1. Study area, the GFCM Geographical Sub-Area 9.
Fig. 1. Area di studio, la sub-area geografica GFCM 9.

Fig. 2 Changes in number of trawl vessels targeting *Mullus barbatus* in the main ports of the GSA9 in the period 1990-2002.
Fig. 2 Evoluzione del numero di barche a strascico, che sfruttano Mullus barbatus, dei principali porti della GSA9 nel periodo 1990-2002.

Fig. 3. Monthly landings per unit effort of the main fleets targeting *M. barbatus* in GSA9 in the period 1990-2002.
Fig. 3. Sbarcato per unità di sforzo mensile di M. barbatus delle principali flottiglie a strascico della GSA9 nel periodo 1990-2002.

Fig. 4. Biomass trends derived from the autumn bottom trawl surveys of the GRUND project (upper line) and spring bottom trawl surveys of the MEDITS EU project (lower line). NOTE: the 1994-2001 MEDITS surveys were performed in late spring early summer; the 2002-2003 MEDITS surveys were performed in summer.
Fig. 4. Stime di biomassa ottenute dalle campagne a strascico sperimentale autunnali GRUND (linea in alto) e primaverili MEDITS (linea in basso). NOTA: le campagne MEDITS 1994-2001 sono state realizzate in tarda-primavera-estate; quella 2002-2003 in estate.

Fig 5. Left: map showing the location of the 6 sub-zones of Geographic Sub-Area 9 and the zone (11) near Sicily coasts used for the composite model. Right: Composite model using Z as a direct index of fishing effort.
Fig 5. Sinistra: mappa con la posizione delle 6 sotto-zone della GSA 9 e la zona (11) lungo le coste della Sicilia, usate per il modello composito. Destra: Modello composito che usa Z come indice diretto di sforzo di pesca.

Fig. 6. Inputs and main results of the Thompson & Bell like model
Fig. 6. Input e principali risultati del modello di Thompson & Bell.

Fig. 7. Sensitivity analysis as regards the four input parameters necessary for the estimation of Z*. The value 1 in the x-axis corresponds to the standardised actual value of each one of the parameters, the lower or higher values correspond to proportional changes of the standardised values.
Fig. 7. Analisi di sensibilità dei quattro parametri di imput necessari per la stima di Z*. Il valore 1 nell’asse x corrisponde al valore corrente standardizzato di ogni parametro, i valori più alti o più bassi corrispondono a variazioni percentuali dei valori standard.

Fig 8. Stock *vs.* recruitment relationships. Replacement lines corresponding to the different biological reference points considered.
Fig 8. Relazione stock-reclutamento. Le linee corrispondono ai differenti punti di riferimento biologici considerati.

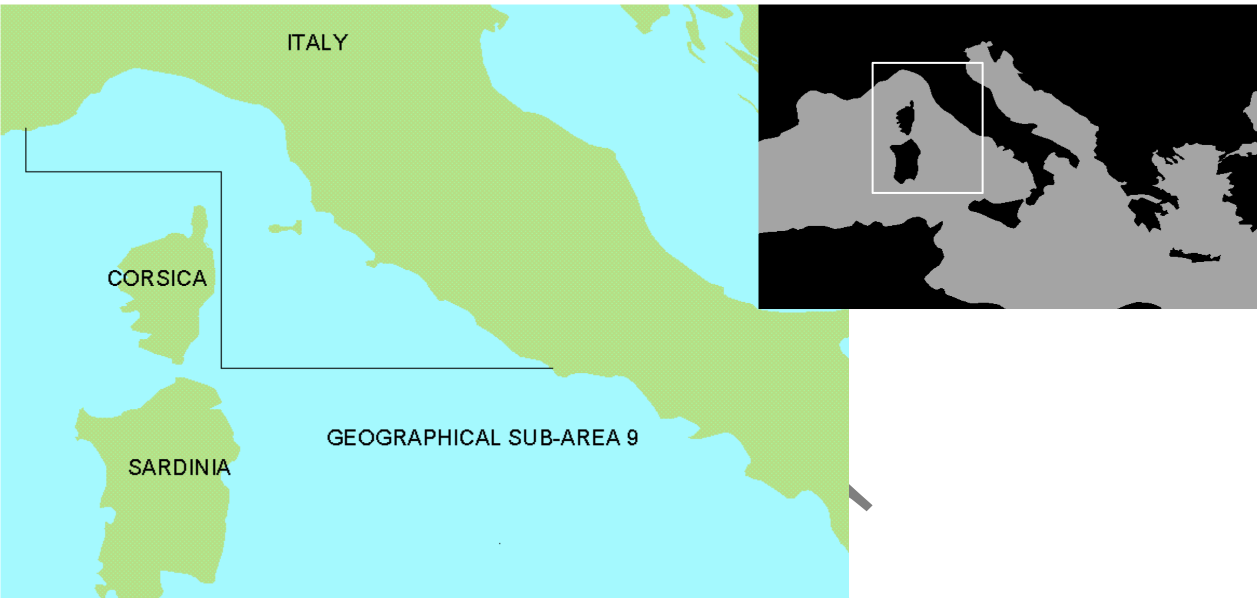

ITALY
CORSICA
SARDINIA
GEOGRAPHICAL SUB-AREA 9

Fig. 1

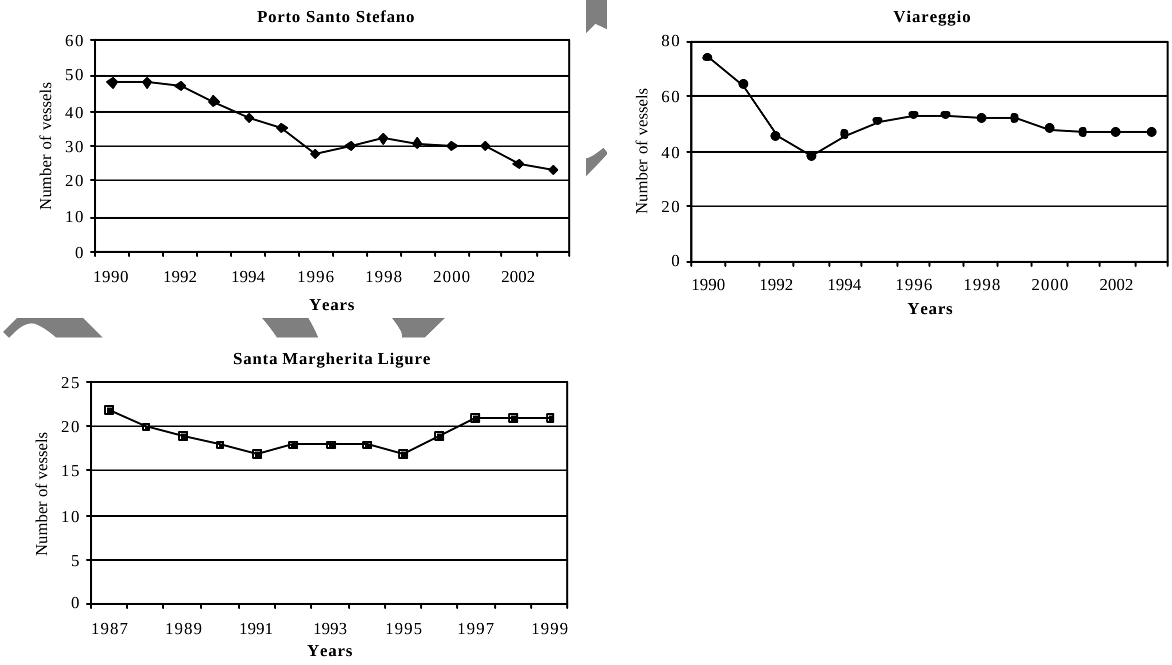

Porto Santo Stefano
Number of vessels
60
50
40
30
20
10
0
1990
1992
1994
1996
1998
2000
2002
Years
Viareggio
Number of vessels
80
60
40
20
0
1990
1992
1994
1996
1998
2000
2002
Years
Santa Margherita Ligure
Number of vessels
25
20
15
10
5
0
1987
1989
1991
1993
1995
1997
1999
Years

Fig. 2

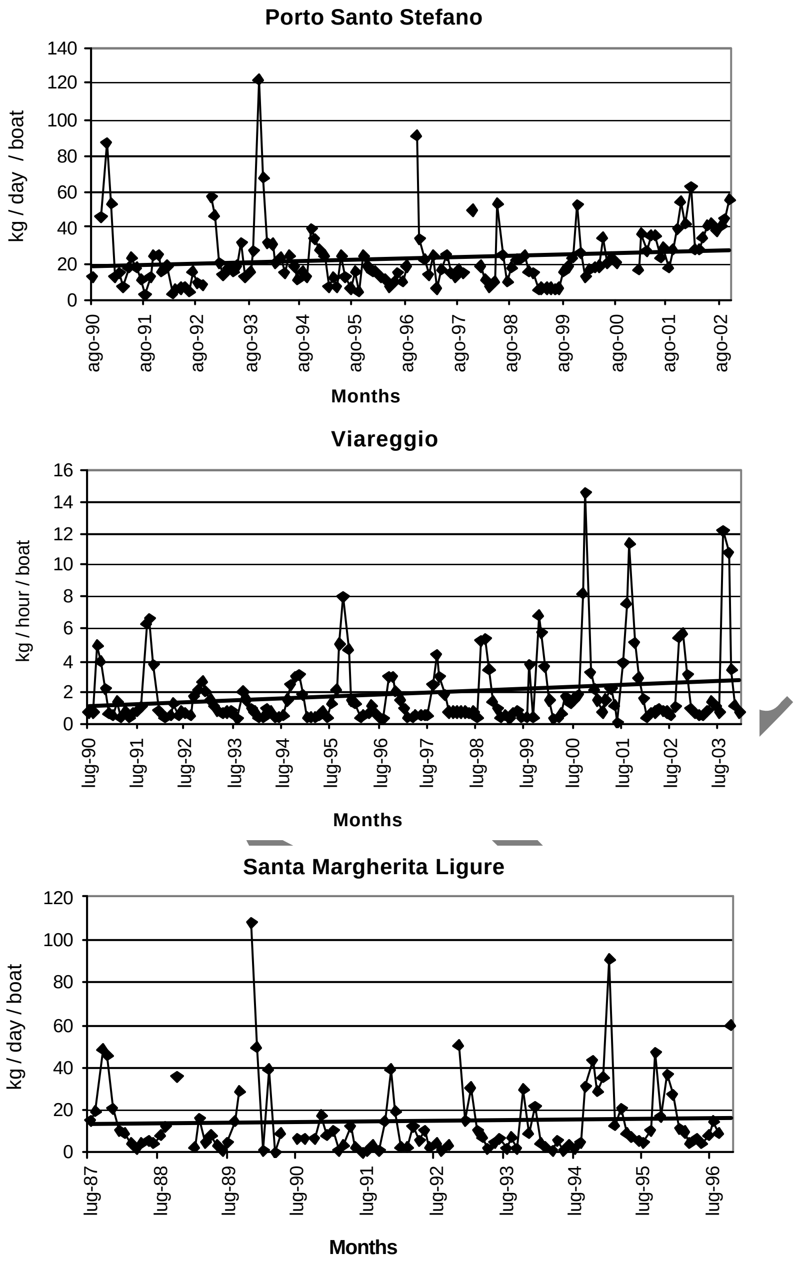

Porto Santo Stefano
kg / day / boat
140
120
100
80
60
40
20
0
ago-90
ago-91
ago-92
ago-93
ago-94
ago-95
ago-96
ago-97
ago-98
ago-99
ago-00
ago-01
ago-02
Months
Viareggio
kg / hour / boat
16
14
12
10
8
6
4
2
0
lug-90
lug-91
lug-92
lug-93
lug-94
lug-95
lug-96
lug-97
lug-98
lug-99
lug-00
lug-01
lug-02
lug-03
Months
Santa Margherita Ligure
kg / day / boat
120
100
80
60
40
20
0
lug-87
lug-88
lug-89
lug-90
lug-91
lug-92
lug-93
lug-94
lug-95
lug-96
Months

Fig. 3

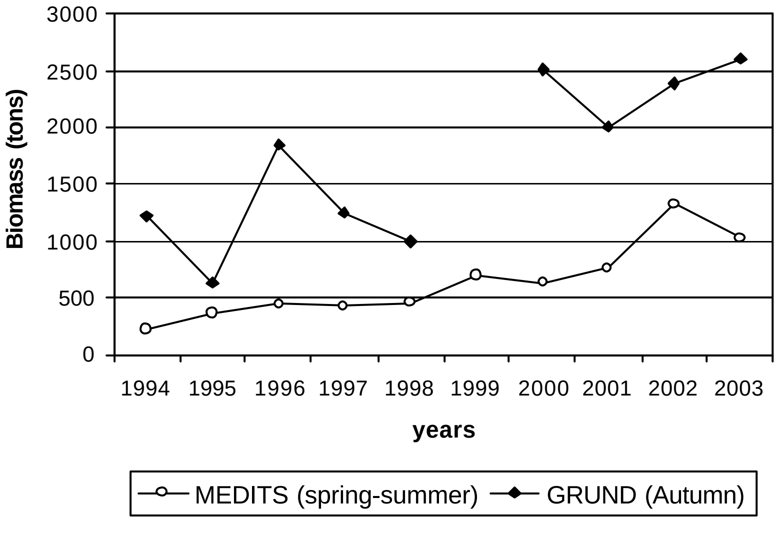

Biomass (tons)
3000
2500
2000
1500
1000
500
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
years
MEDITS (spring-summer)
GRUND (Autumn)

Fig. 4

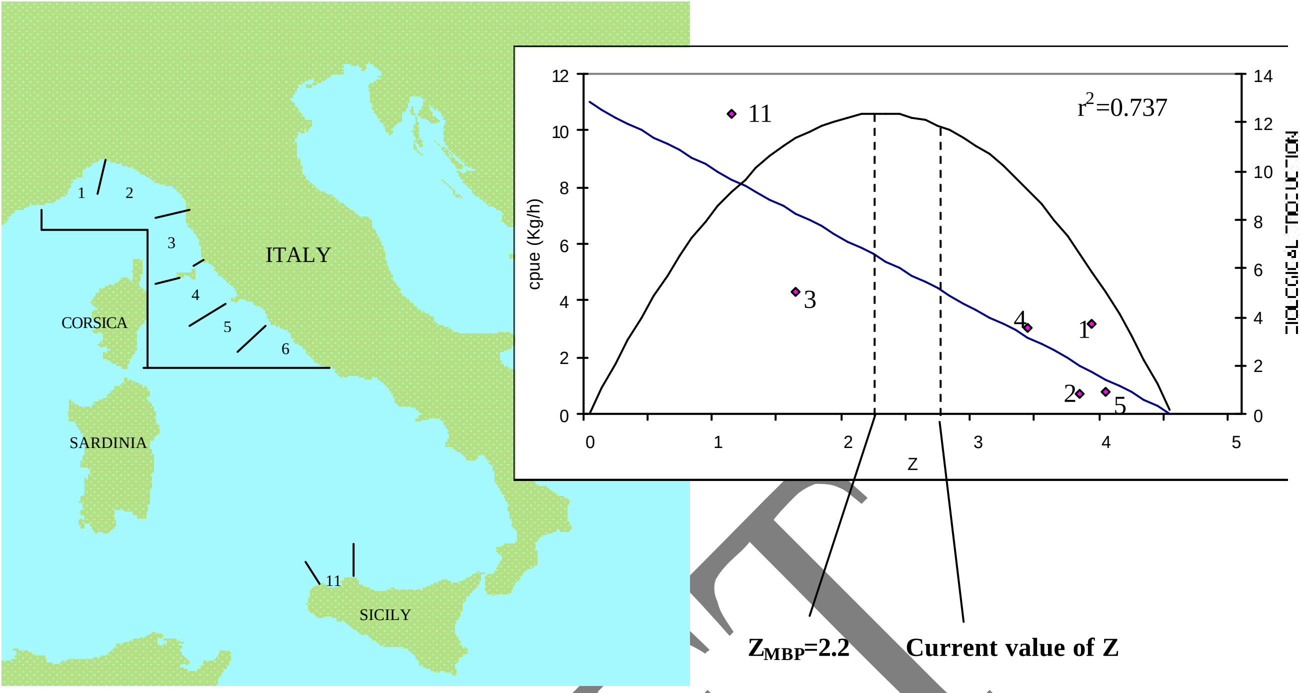
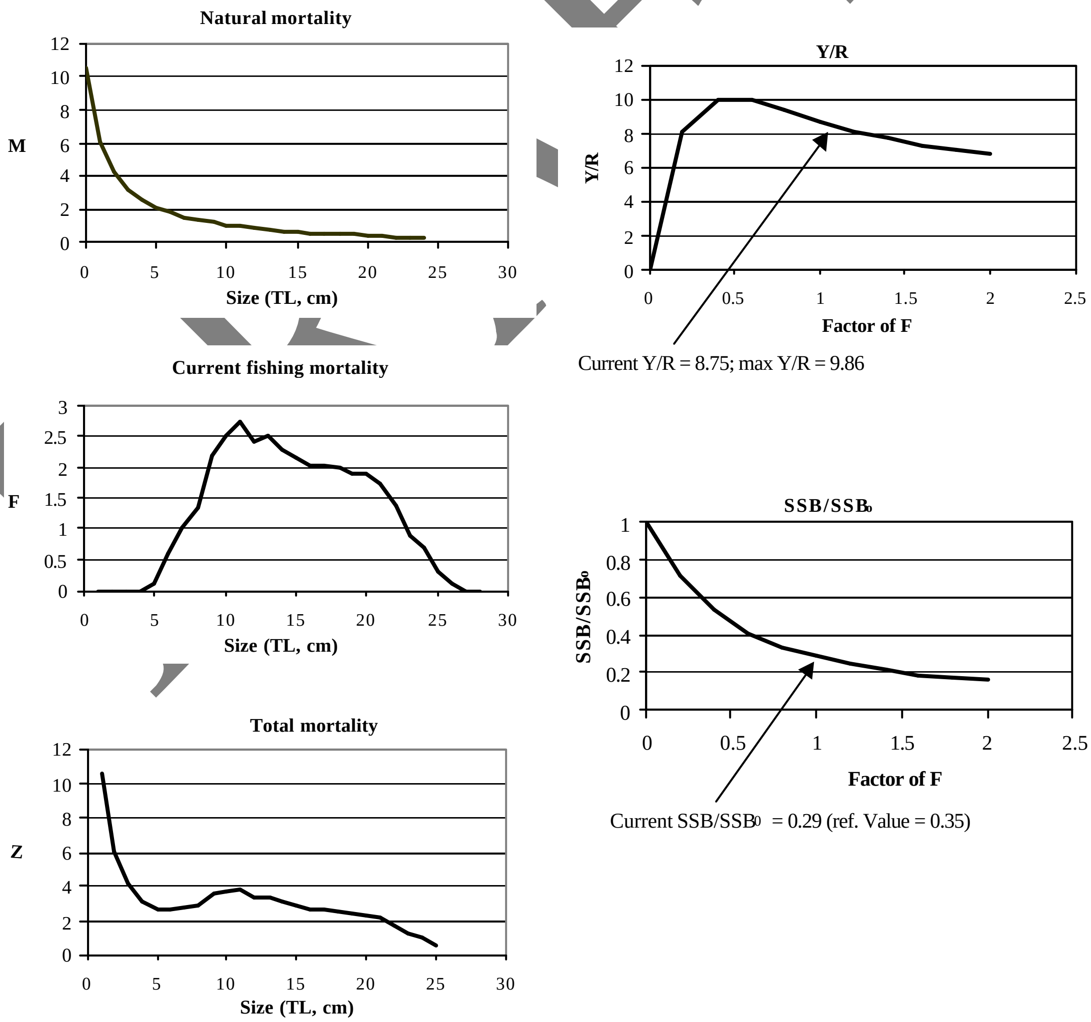


Fig. 5



Current Y/R = 8.75; max Y/R = 9.86

Current SSB/SSB0 = 0.29 (ref. Value = 0.35)

Fig. 6

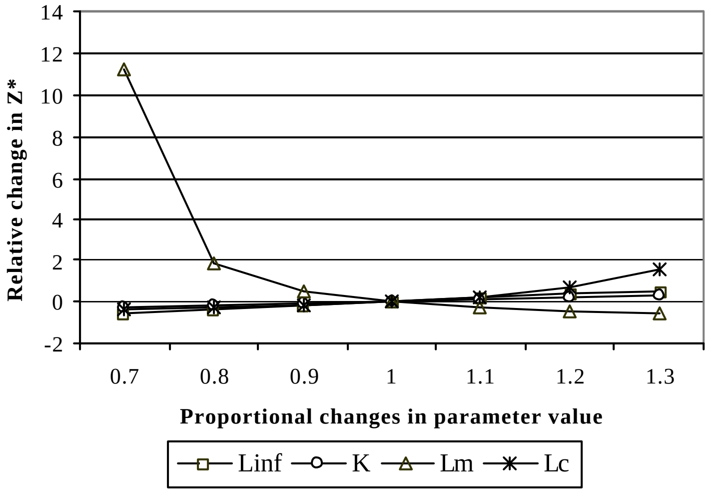

14
12
10
8
6
4
2
0
-2
Relative change in Z*
0.7
0.8
0.9
1
1.1
1.2
1.3
Proportional changes in parameter value
Linf
K
Lm
Lc

Fig. 7

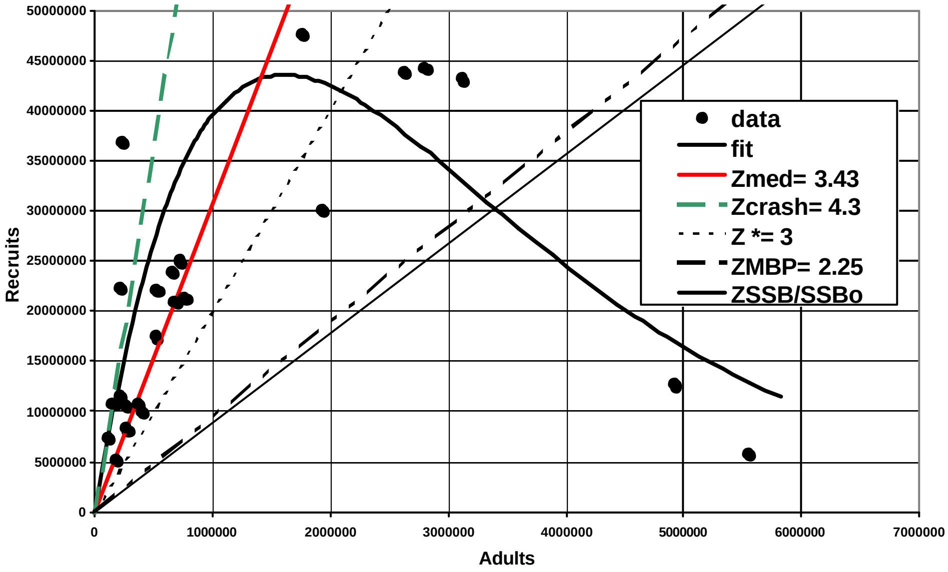

50000000
45000000
40000000
35000000
30000000
25000000
20000000
15000000
10000000
5000000
0
Recruits
0
1000000
2000000
3000000
4000000
5000000
6000000
7000000
Adults
data
fit
Zmed= 3.43
Zcrash= 4.3
Z *= 3
ZMBP= 2.25
ZSSB/SSBo

Fig. 8

Table 1. Common Biological parameters considered representative for M. barbatus in the GSA9 utilized in the analysis.

Parameter	Value	Source
L_{inf}	29.2 cm TL (females) 22 cm TL (males)	Voliani *et al*., 1998
k	0.68/year 0.74/year	Voliani *et al*., 1998
L_m	12.5 cm TL (females) 10 cm TL (males	Sanchez *et al*. 1995
L_c	7.4 cm TL (males + females)	De Ranieri *et al.*, 2000

Table 2. Estimated values of Z for the different BRP's and corresponding Y/R and SSB/SSBo that are expected in the case the stock is exploited with these rates.

Current status	Z	Y/R	SSB/SSB_0
	2.72	8.75	0.29

Biological Reference Point	Estimated value	Corresponding value of Y/R	Corresponding value of SSB/SSB_0	Change of F necessary to reach the chosen BRP
Z*	3	8.38	0.26	+ 14%
Z_{MBP}	2.25	9.45	0.34	- 28%
Z_{med}	3.43	7.89	0.23	+ 33%
Z_{crash}	4.22	7.16	0.18	+ 71%
$Z_{SSB/SSB_0=0.35}$	2.19	9.53	0.35	- 25%

REFERENCE POINTS: A BIO-ECONOMIC MODEL BASED APPROACH

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Key words: *Fishery management; Fishing effort; Mathematical models; Multi-species fisheries; Reference levels.*

Abstract

The concept of Reference Points (RPs) is closely connected to the management objective which, by also involving economic and social issues, may not be restricted to the sole biological maximization (MSY).

It is possible to define different RPs for each aspect of management or to identify a single RP aimed at ensuring the sustainability of the system, no longer limited to biology, but affecting environmental, economic and social features that involve the state of system as a whole. The latter is described as a multi-criteria RP.

This paper briefly outlines the main RPs obtained by applying the bio-economic optimisation models of effort and effort-catch, with specific reference to the Gordon-Schaefer model, which clearly derives from the theory of population dynamics.

The debate about the effectiveness and the efficiency of both the indicators and the RPs that are potentially useful in mono-species fishery is here conducted with respect to the multi-specific character of Mediterranean fishery and the different selectivity of employed gears. Accordingly, as regards the Mediterranean context, we recommend the adoption of a multi-criteria approach based on bio-economic optimisation models which, by introducing a number of restrictions, would allow the definition of the actual state of the system as well as specific management targets.

1. Introduction

The UN Convention on the Law of the Sea of 1982 and the outcomes of the Rio de Janeiro Conference of 1992 allowed the adoption of the FAO *Code of Conduct for a Responsible Fishery* (1995). The latter was a turning point in the States commitment to the preservation and the management of natural resources. In order to ensure the actual conservation and management of resources, this Code of Conduct establishes and recommends the adoption of international principles and models of behaviour focussed on the respect for both natural ecosystems and biodiversity. Accordingly, the concept of sustainable development is described as *"a development that would meet the needs of the present without endangering the future generations' capacity to meet their own needs"* (WCED, 1987). This statement, which strongly evokes the principle of "sustainability", is worldwide regarded as the major guideline for policies concerning the management of marine resources. According to this principle, the Governments are to adopt an ecosystem-based approach. This involves the sustainable management of both commercial stocks and specific ecosystem factors that support the production such as the socio-economic quality of the sector. In other words, the ecosystem-based approach extends the management of the fishery from that of commercial stocks to that of the interaction between fishery, human and natural related systems.

In line with the above-mentioned principles, a sustainable development of the fishing sector requires that the actors involved in the preservation of the environment assume wider responsibilities. To this end, a clear and updated informative framework should support the socio-economic development oriented towards the preservation of the environment. The complexity, the uncertainty and the worldwide distribution of the issue call for the development of informative tools on which to base both a methodological organisation and an effective representation of reality.

A sustainable management policy is to be implemented by taking clear and specific steps, which can be summarised as follows:

1. to set the sub-goals to be achieved in order to ensure the exploitation of the marine resources belonging to the ecosystem;
2. to identify one or more indicators of sustainability for each goal;
3. to establish, for each indicator, one or more reference values through which a given situation may be considered as acceptable or undesirable; and
4. to define the measures to be implemented in order to achieve objectives determined on the basis of the specific conditions of the system, which is identified through the relevant indicators and reference values.

Once the objectives have been identified, the further step to be taken is the choice of the indicators. These are to play a considerable role as information and communication tools within the decision-making process. In a given moment, by adopting these indicators it is possible to draw an accurate picture of the sector in terms of exploitation of marine resources, environment conditions, and environmental and social impact. This information enables us to formulate hypothesis of intervention directed at improving the reference framework.

The position of the sustainability indicator associated with the reference values will describe the current state of the system and provide us with the relevant input to evaluate the situation and make management-oriented decisions.

In order to effectively interpret the information obtained through a specific indicator, some reference values are applied (RPs, reference points). These values can be associated with either a difficult or an optimal (or sub-optimal) situation. The former identifies a limit which is necessary to avoid (LRPs, limit reference points), while the latter represents a target to be attained by the system (TRPs, target reference points).

2. Reference Points

The idea of reference points is strictly related to the management objectives to be attained. For instance, the Maximum Sustainable Yield (MSY) is the reference value to be applied in order to reach the maximisation of production. However, management objectives usually include social and economic aspects, such as the profitability of fishing activities, the maintenance of employment levels and the safeguard of local economies strictly dependent on fishery. Thus, in order to ensure the environmental, economic and social sustainability, it is possible to define different reference points associated with each aspect of the sector or, to identify a single reference value that encapsulates all the aforesaid aspects. Furthermore, given that a single management aim would only meet the interest of a specific group of stakeholders, a management-oriented reference point should be agreed upon and shared by the stakeholders as a whole. As a consequence, the sharing of monitoring and control tools entails a multi-objective approach in which the different interests at stake are evenly represented.

As previously stated, reference points can be subdivided into two groups following their different use, such as: Limit Reference Points (LRPs) and Target Reference Points (TRPs) (Caddy e Mahon, 1995; Caddy, 1998). The LRPs consist in a definition of the thresholds that the resources or the sector indicators are not to overcome. Indeed, the overcoming of these thresholds would produce an irreversible long-term crisis affecting the resources and the sector as a whole. According to the reference indicator, LRPs can be associated to either minimum or maximum levels. The reaching of these limits should stimulate the implementation of comprehensive management measures directed at bringing the indicators back to levels considered as acceptable.

A quite different approach is required to define TRPs, which are usually related to indicators associated with the condition of stocks. These indicators represent the desirable level of stocks and, therefore, an objective to be pursued using appropriate management measures. TRPs may concern either the input or the output of the productive process. Accordingly, they might enable us to determine the optimal levels in terms of the size of catches, fishing effort or sector profitability.

3. The reference points within a mono-species fishery

The most widely used management-oriented Reference Point (RP) is the Maximum Sustainable Yield (MSY). As far as the fishing effort is kept constant until the system reaches its equilibrium, the MSY indicates the highest point of the curve that describes the functional relation between the annual fishing efforts made by the fleet and the resulting production. Apparently, this RP represents the natural aim of mono-species fishery. Indeed, in the 60s and the 70s, it was widely applied by stakeholders. Nevertheless, further theories questioned the usefulness of the MSY with reference to the preservation of marine resources and suggested new approaches.

Like other RPs, the MSY is designed to meet a specific production model. Therefore, the reliability of the MSY depends on the consistency of this model with the reality. The most widespread models are the logistic or Schaefer model (1957), the Fox model (1970) and the Pella and Tomlinson model (1969). All these models are estimated by using the time series data of catches and effort: the relation between the two time series allows setting the optimal value of catches at a desirable level of effort. Figure 1 shows the curve of sustainable profits obtained by using the Gordon-Schaefer model (1954). Obviously, the curve will change following the different models and the RP value.

The most common arguments against the adoption of the MSY as an RP concern the uncertainty of the estimation and the consequent risk of overcoming the optimal level of effort. The RP estimation depends on both the reliability of the data and the correct specification of the model, as well as on the degree of randomness that characterizes this phenomenon. Besides, the MSY estimation through time series data is conducted by assuming that the previous conditions will occur in the future with the same probability. Actually, any substantial change in the structure of the population along with the variations affecting the behaviour of the phenomenon, which may occur in variables not considered by the model, would turn the MSY and the effort estimation away from their true values. Furthermore, the adoption of the MSY as an RP will inevitably lead to a state of over- or under-exploitation, which would require repeated management interventions. Indeed, stocks react quite differently to the two previously mentioned situations that cannot be considered as symmetric. As evidenced by Beddington and May (1977), once the level of effort that corresponds to the MSY has been overcome, the stock fluctuations become wider and the time span needed to re-attain the equilibrium increases considerably.

The criticism about the adoption of the MSY as an RP led to a more cautious approach that takes into account the uncertainty of the system. A possible solution, maintained by Doubleday (1976), foresaw the setting of an optimal level of effort as equal to two-thirds (2/3) of the effort indicated by the MSY. (*2/3 Emsy*, see Fig. 1). This effort level, which corresponds to 80% of the MSY in terms of catches, entails a considerable decrease in the risks discussed above.

A different solution might be represented by an economic approach to the RPs designing. Several studies proposed the adoption of the Maximum Economic Yield (MEY) as an economic RP. This RP also originates from logistic models, as the Gordon-Schaefer equilibrium model. The MEY is equal to the level of effort in which the maximum profit is achieved. In other words, it corresponds to the highest difference between revenues and total costs. Given the cost function as linear, the MEY value is positioned before and below the MSY (that is, left of the MSY, see Fig. 2). Since the effort that corresponds to the economic optimum is lower then that of the biological MSY, the adoption of the MEY as an RP will reduce the risk of overexploitation of resources. The level of effort associated with the MEY is likely to fluctuate as a consequence of the changes in the variables of the reference economic framework, such as the cost of fishing activities and the price of landings. When the price is a function of the catch quantity and, therefore, of the offer, low levels of catches may also correspond to higher profits. In these cases, the economic optimum will be positioned further left in the long-term equilibrium curve.

To sum up, the efficiency of the solution discussed above can be considered as equal or more effective than the Doubleday solution, which makes MEY more helpful (usable) than MSY.

4. The problem of multi-species fishery

The main hindrance to the adoption of the so far discussed RPs (MSY, MEY) is that they are based on models designed for mono-species fishery. In most cases, the fishing sector is characterized by a number of fishing systems which harvest a wide range of species. Particularly, within the Mediterranean, which hosts a number of animal and vegetal species and involves a fishery performed with lowly selective gears, the mono-species approach would prove to be completely ineffective. Given the large biological and technical interactions within the area, a management system based on single species RPs would be totally unfeasible. Indeed, the same fishing effort will be directed to harvesting different species, to which different MSYs and levels of optimal effort might be applied.

Figure 3 provides a clear example of this situation. Within this system fishery targets three species, each species has its own MSY. If we consider the aggregate catches by summing up the curves of sustainable production for each single species we may obtain an MSY corresponding to the optimal effort *Emsy* through which we may determine the impoverishment of the less productive stocks. In the case under discussion, species no. 3 is doomed to become extinct if we adopt the point equal to *Emsy* as the level of long-term effort. Given these circumstances, wiser approaches, as the adoption of the two thirds (2/3) of the MSY effort as the optimal effort level, may no longer prove to be helpful. As regards stocks preservation, from a precautionary viewpoint, the only feasible solution would be to define an RP which incorporates the species most vulnerable by fishery (in Fig. 3, species no. 3). Assuming that this choice might prevent marine resources from being over-fished, nevertheless its huge socio-economic costs would make it totally unfeasible.

Within a multi-species context, the mono-species economic approach (MEY) also follows different and much more complex guidelines. Compared to the MSY level, the level of effort corresponding to the MEY can no longer be considered as a prudential value. Indeed, since it depends on the ratios between the prices of the different species, it is likely to be positioned either on the left or on the right of the *Emsy* value. The latter case is expected to occur when consumers' choices determine an higher price of the most productive species. If species with higher *Emsy* also have a higher market value, the *Emey* value will be positioned to the right of the *Emsy* value. Figure 4 illustrates this case: compared to species no. 2 and 3, species no. 1 shows a significantly higher price. This determines an MEY effort (*Emey*) higher than the effort related to the MSY (*Emsy*). Conversely, when a higher price is associated with species whose intrinsic growing rate is lower, the MEY will be found on the left of the MSY. However, in this case the equivalent level of effort will not ensure the prevention of species belonging to the productive mix from being over-fished**.**

In a multi-species fishery, such as the Mediterranean, the adoption of an RP derived exclusively from a biological or an economic model would be only partially applicable. In other words, it would not represent the optimal solution. On the contrary, we suggest the adoption of a multi-objective approach directed at maximizing the economic outcome that also takes into consideration the need for stock preservation. This scheme is based on the use of bio-economic models that summarize the long-term behaviour of the system in a context of optimal sustainability. Tailored to multi-species fishery, the approach based on the Gordon-Schaefer model will be discussed below as an example of a viable method. Nevertheless, it is also possible to adopt more complex and detailed models, which would take into account the biological features of the different species**.**

5. A multi-objective approach

Within a single fishing area, this model aims at determining the optimal level of fishing effort per each segment of the fleet. Therefore, the effort obtained using this method is to ensure the attainment of the maximum economic outcome (in terms of added value) consistent with the need for preservation of the species (biological restriction). Thus, the problem can be represented as follows:

$$\max_x VA(x) = R - C$$
$$\text{s. v. } VB(x) < VB_{max}$$

where *R* stands for the revenues obtained by summing up the values (per single species) of the catches (each species multiplied by its selling price). In addition, *C* describes the aggregate operative costs obtained per each segment of the fleet by multiplying the unitary cost of the fishing activity (not including labour cost) by the overall fishing effort. The average and the unitary prices of the fishing activity can be obtained from the time series data. Since 1985, a monitoring of the Italian fleet conducted by IREPA with a methodology of statistic sampling enables us to estimate the above-mentioned data. The vector *x* represents the variables to be optimised; that is, the level of effort pertaining to each segment of the fleet operating in the relevant area. The prices and the costs of the year of consideration, together with the time series of catch and effort are then used to establish the optimal levels of effort.

The maximization of the added value concerns segments of the fleet (identified on the basis of the fishing system used) rather than single productive units (vessels). Therefore, we indirectly assume that all fishing units have a similar behaviour and that their actions are cumulative. Thus, providing that the above-stated conditions are satisfied, it is possible to include these micro-economic features in the optimisation algorithm. The added value obtained will then represent the returns of the productive sector, that is, the capital and the work, which are difficult to be distinguished within the Italian fishery (Placenti *et al.*, 1992).

As previously stated, the level of effort directed at achieving the Maximum Economic Yield (MEY) cannot be used as an RP within multi-species fishery since it does not ensure the preservation of the species as a whole. In order to avoid *over-fishing* and consequently the significant impoverishment of the most vulnerable species, a biologic restriction (VB) has been included in the methodology. For each equation effort-catch, that is, for each species, a biological term VB_i has been defined. This stands for the excess of effort compared with what we consider as an economically optimal effort. For species that are not over-exploited, this is equal to zero:

$$VB_i = E_i - E_{m,\,i} \qquad \text{se } E_i > E_{m,\,i}$$
$$VB_i = 0 \qquad \text{se } E_i \leq E_{m,\,i}$$

where $E_{m,\,i}$ represents the effort that, in a state of biological equilibrium (MSY) of the *i*-nth species, corresponds to the maximum catch. This value depends on the effort-catch model adopted. As for the Schaefer model, where the catches pertaining to a single species are a function of the fishing effort according to the parameter k_0 and k_1, we consider that:

$$C_t = k_0 E_t - k_1 E_t^2.$$

This value is obtained by

$$E_{m,\,i} = k_0 / 2k_1.$$

For each area, the biologic term VB is calculated as the ratio between the sum of the terms VB_i for each species and the total effort within the relevant area:

$$VB = \sum VB_i \,/\, \sum E_i.$$

This index can be read as the fraction of the aggregate effort that exceeds the condition of maximum catch (MSY) for each species. Figure 4 shows the excess of effort represented as segments AB and CD, which measure the excess of species no. 2 and no. 3 respectively. The sum of the two segments corresponds to the biological term VB. If a maximum limit VB_{max} is assigned to VB, the level of effort to be adopted as an RP will be positioned on the left of the MEY effort (*Emey*).

The bio-economic model of optimisation is directed at determining the economic optimum that would allow a level of exploitation of the most vulnerable species not exceeding the pre-established VB_{max} value. The higher the value assigned to VB_{max}, the closer to the MEY is the optimal level of effort to be considered as a TRP. On the other hand, the lower this value is, the closer we may get to a TRP coinciding with the MSY of the species which are most likely to be negatively affected by fishing activities. The simulations conducted through this model allow assessing the economic and social consequences of the several values attributable to VB_{max}, and the different influence assigned to the environmental factor.

The model discussed above takes into account only environmental and economic issues. Nevertheless, other factors can also be considered. For instance, if the model is applied to a fishing activity performed in a situation of over-exploitation, this will require a TRP lower than the current value, thus urging the operators to immediately reduce the effort. This decrease may concern any segment of the fleet operating within the relevant area. It is clear that a decrease in the capacity, i.e. a reduction of the number of vessels, may produce social damages which would vary according to the fleet segment examined**.** Thus, it is possible to introduce a further restriction directed at safeguarding the segments of the fleet that either ensure higher levels of employment or have lower impact on the ecosystem. A further issue is related to the importance of fishing activity within local economies strictly dependent on fishery or with high unemployment rates. In these cases, the approach to be adopted should take into account economic and social issues rather than the mere environmental ones.

The structure of the restrictions can be further modified and tailored to meet the specific requirements of the management tools, which we intend to adopt in conjunction with the prearranged objectives. Given that the re-arrangement of the fishing effort among different areas and segments of the fleet is the main management objective, once the optimal level per each area has been established, the best allocation of the exceeding effort can also be determined (Placenti *et al.*, 1995). In this case, to support the feasibility of the management measures and the relevant RPs adopted, the occurrence of further management costs should also be taken into account. To this end, it is possible to measure the differences between the proposed solutions and those that have actually been applied. Thus, an inertial term VI_i has been defined for each fishing system and area:

$$\begin{array}{ll} VI_i = \left| E_i - E_i^* \right| - DE_i & \text{se } \left| E_i - E_i^* \right| > DE_i \\ VI_i = 0 & \text{se } \left| E_i - E_i^* \right| \le DE_i \end{array}$$

where DE_i stands for the maximum variation permitted around the reference value for the effort E_i^* obtained using the following formula: $DE_i = \mathrm{StDev}(E_i)F$. The DE_i value is then proportional to the standard deviation of the i-nth effort over the period of time considered within a given area and segment of the fleet. The F factor may vary according to the different scenarios and the management objectives considered by the optimisation analysis. Within each area and fishing system, this procedure allows taking into account the *elasticity* shown by each fleet over the previous period.

For each area, a comprehensive term VI is then calculated as follows:

$$VI = \sum VI_i.$$

The inertia term allows limiting the variations of the current distribution of the effort while avoiding the implementation unfeasible solutions. Also it helps us select the optimal distribution that would require lower effort and re-conversion costs while ensuring equivalent biological and economic outcomes. Given the application of this further restriction, the RPs will be identified by solving the following constrained optimisation problem:

$$\begin{aligned} &\max_x VA(x) = R - C \\ &\text{s. v. } VB(x) < VB_{max} \\ &\qquad VI(x) \leq 0 \end{aligned}$$

In this case, the model becomes more complex and permits to identify the TRPs that could best meet environmental, economic, social and management needs by assigning the appropriate values to VB_{max} and F.

6. Conclusions

Within the fishery sector, the multi-objective approach based on bio-economic models permits to take into account the various interests supported by stakeholders. Their objectives do not necessarily diverge. In fact, when considering long-term solutions, interests may coincide. However, management measures may also be implemented so as to produce the least inequality among the different groups of stakeholders. Furthermore, the objectives and the relevant variables included in the model may evidence specific synergies and relationships. The knowledge of the system and its rules allows finding solutions that would meet the interests of certain groups while causing the least possible disadvantages to those of others. This knowledge is represented by the equations included in the bio-economic models, which, by taking into account all the interests at stake, enable us to find the optimal solutions. Obtained through the adoption of constrained optimisation techniques, these solutions require an object-oriented function. In the case examined in the present paper, the latter is represented by the maximum economic profit. Additional restrictions direct the search for the optimum towards a set of solutions considered as desirables. These are aimed at safeguarding the marine resources and avoiding their impoverishment. Also, they should preserve employment levels, support local economies and, above all, rather than exclusively consider the welfare of fisheries, take into account the interests of the society at large.

As a consequence, the multi-objective function enables us to shift from RPs merely based on population dynamics to TRPs that represent the operators' consent to take full responsibility for the social aspects involved in their activities. Accordingly, in a multi-objective perspective, bio-economic models allow searching for the optimal levels of effort in which the importance of each aspect determines the weight of the resulting restriction within the optimisation model. All stakeholders shall then contribute to define these weights. Thus, by simulating the outcomes of those choices on the system as a whole, the model may prove to be extremely useful in this phase.

Summary

In this paper we propose a multi-objective approach with a view to identifying reference points in multi-species fishery. Our approach is based on bio-economic models and particularly on the Gordon-Schaefer model. The paper shows that, a purely biological or economic approach can be adopted in mono-species fishery. However, the same approach proves to be useless in multi-species fishery. The multi-species and multi-fleet catch-effort model we suggested allows taking into account the biological,

economic as well as the social aspects related to fishery. In terms of fishing effort, this comprehensive model also permits to identify a reference point, which ensures the achievement of an economic objective (maximum profit), without neglecting the biological and social sustainability of the system.

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Figures

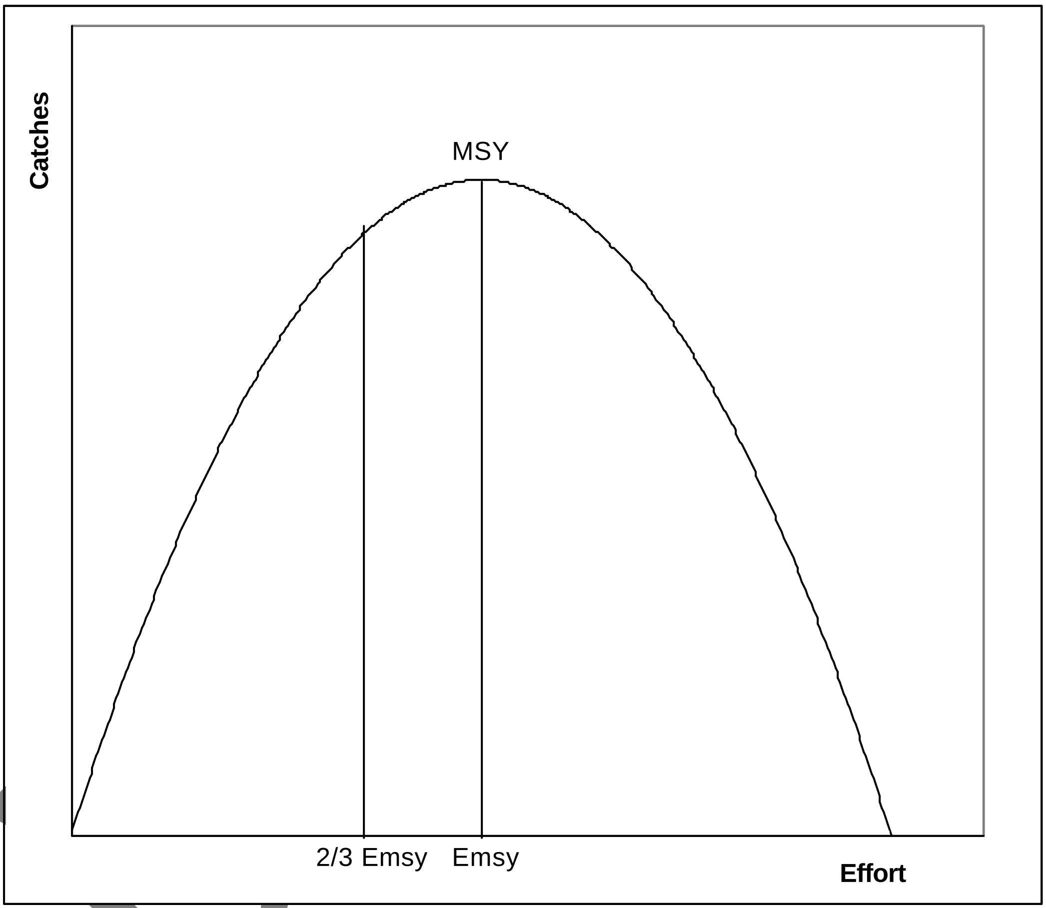

Fig. 1 - Gordon-Schaefer model. *Emsy* and *2/3Emsy* identification.

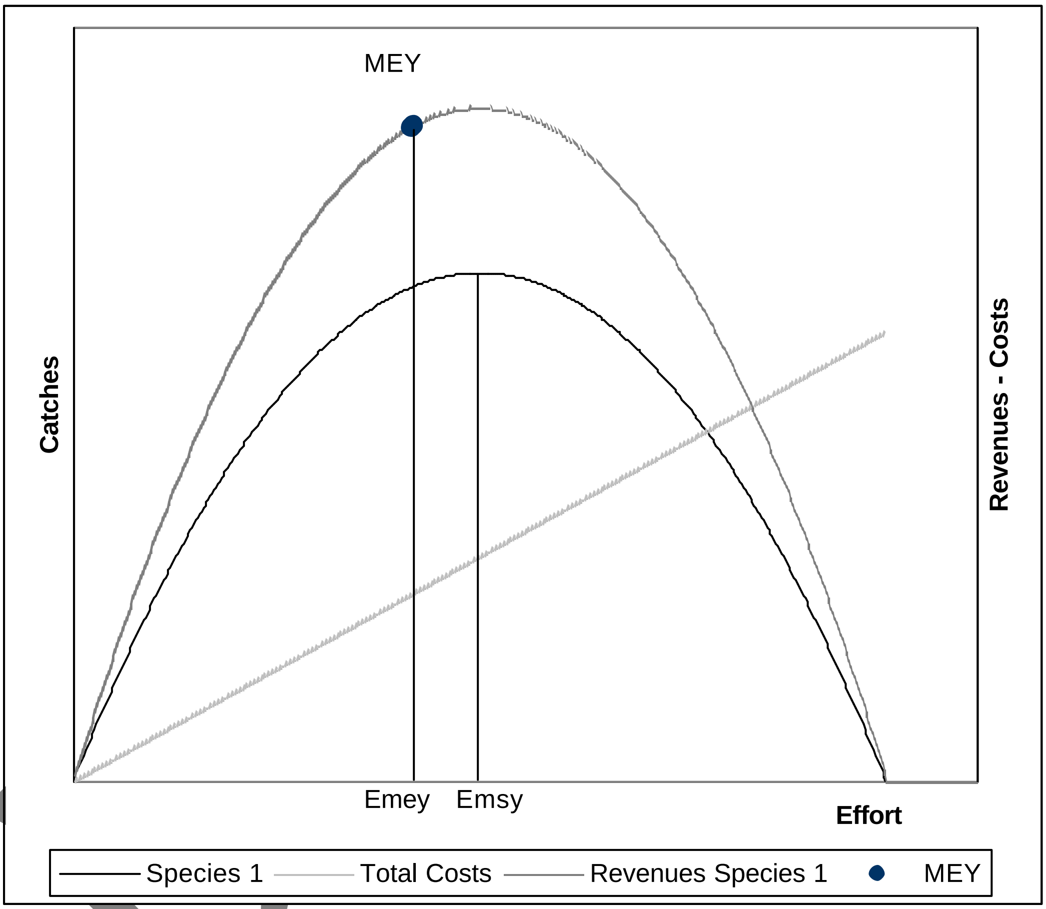

Fig 2 - Gordon-Schaefer model. *Emsy* and *Emey* identification.

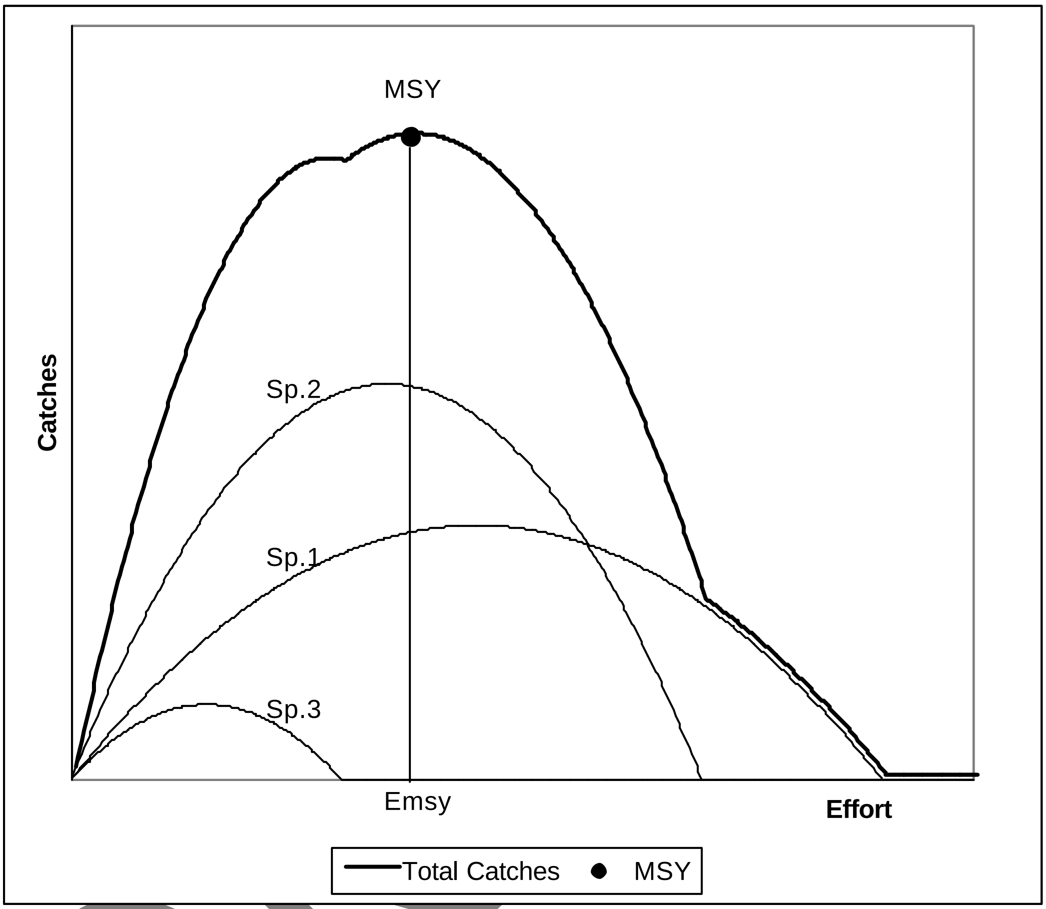

Fig. 3 - Gordon-Schaefer model in a multispecies fishery. *Emsy* identification.

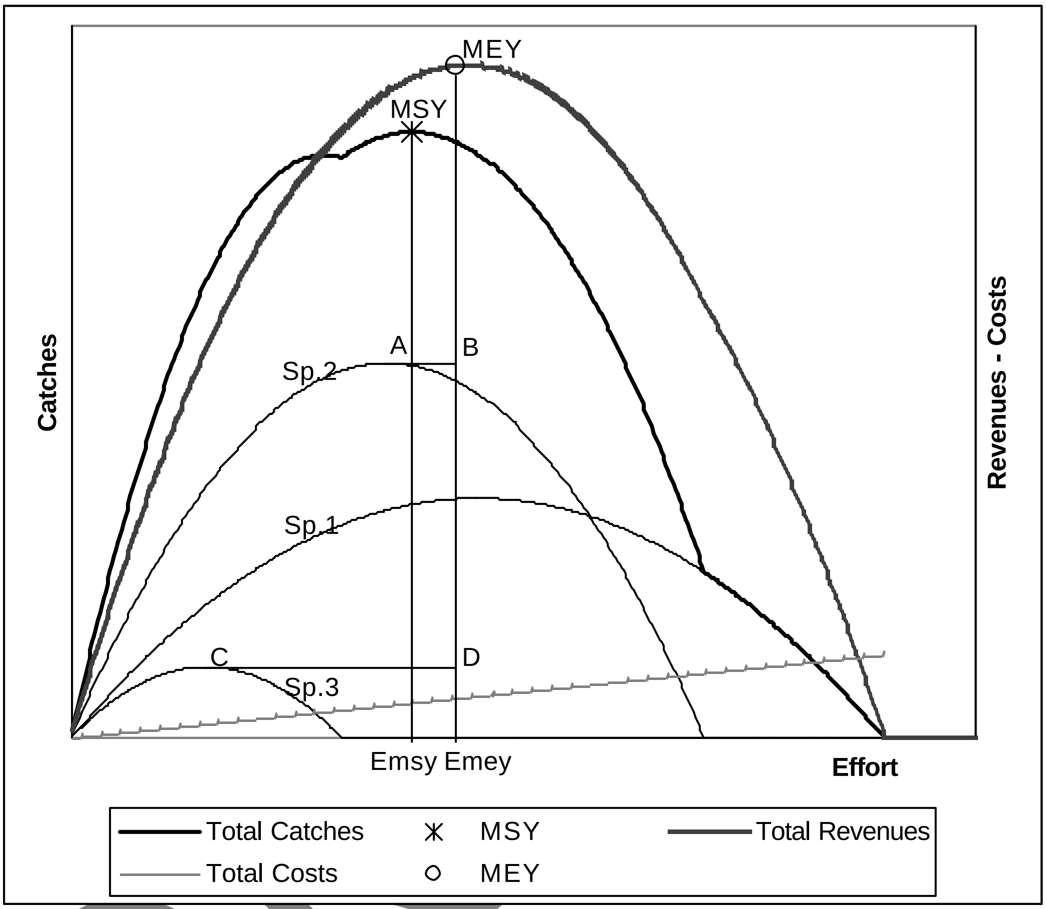

Fig. 4 – Gordon-Schaefer model in a multispecies fishery. *Emsy* and *Emey* identification.

GENERAL CONSIDERATIONS ON REFERENCE POINT IN THE MEDITERRANEAN FISHERY

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Abstract

It is advisable to adopt Biological Reference Points for the Mediterranean fishery sector. At this aim, the data concerning the values of total average biomass per year and per area are very important. There is a need to develop research in stock assessment (using population dynamics on trawl survey data) based on a sound and reliable sampling scheme in the space and time. Moreover to strengthen supporting the research conclusions, a comparison with commercial catch data seems opportune. Unfortunately commercial catch data, today, are not available to the Italian scientific community.

Key words: Reference points, Fishery management, Mediterranean Sea.

Introduction

I personally reckon that in Italy and in general in the Mediterranean, Reference Points should be based mainly on biological data.

The introduction of economical (prices, alimentary customs etc.), bio-economical and technological aspects, to be analyzed simultaneously with biological data is very likely to hinder the capability of understanding of the whole system and thus of assessing the state of resources. In this first phase the aim should be to reach a sustainable exploitation of fishery resources based on a philosophy of preserving these resources (FAO, 1996).

In a second step economical and bio-economical considerations and data should be added, while technological information should accompany and sustain the management indications, once the stock assessment and management indications are in place and running.

This seminar should then be the occasion not only to enlighten what has been done up today, but also to propose some structural changes which could better follow the enforced EU regulations.

It seems also opportune to introduce in Fishery science the concept of “fishery physiognomy” of an area or of a basin and to point out some possible points for in depth reflections in the process of fishery resources evaluation.

1 - Towards an identification of R.P.

To reach the identification of R.P. in the Italian fishery there is a need for theory, pragmatism, common sense and the start of a systematic monitoring of resources (this last should be a permanent duty for the Government to the public); this is because the development of the Italian Fishery has been constrained by rules not always applied, corporative interests, structural deficiencies and resources fully to overexploited.

It is therefore of paramount importance to improve fishery statistics which should be made by sample for fish production and by census for global fishing effort (E). CPUE should be evaluated for samples of the professional fleets and integrated by field scientific sampling (trawl survey, echosurvey, etc.). Cohort analysis should be performed by scientists to assess the level of exploitation of the main stocks. This could allow the Administration to answer to EU regulations and to make reliable forecasting for the governmental triennial fishery plans. But unfortunately this is not the case at present.

2 - The fishery-ecological characteristics (physiognomy) of the basins

First of all it is necessary to evaluate which species are more important (in weight) in the catches in a certain basin and determine its fishery-ecological characteristics (physiognomy).

Fish and macroinvertebrates exploited by the fishery are mainly on the third trophic level in the ecological food chain. Their abundance, by means of a rough back calculation, could give an idea of the primary and secondary production of the basin. But the ecological characteristics of the various group of species (dwelling on soft or hard bottom, on shelf or slope, benthic, nectobenthic or pelagic, coastal or offshore, etc.) with some species dominant in terms of abundance (as indicated by catches), gives us an idea of the physiognomy fishery-ecological of a certain area. For instance data on distribution of a stock of a mud dwelling species can give an idea of the extension of this substratum and which fishing gear can be used.

In conclusion, the statistical catch data, are not only quantitative but, ecological data too. In that way, dividing the basins in the unitary areas we can obtain the fishing intensity distribution (f/A) and fishing productivity per area or the abundance per area (C/A). In this way a ranking of productivity for areas and basins can be obtained and comparisons can be made. For instance we could try to compare, at the same level of fishing intensity (f/A), what is the value in terms of productivity (Catch/A or Biomass/A) of a square nautical mile in the Central Adriatic versus one square nautical mile in the Tyrrhenian, in the Sicilian Channel, in the Aegean or in the Balearic sea. This kind of investigation have been already done in same case (Bombace and Cingolani, 1987; Ardizzone *et al.*, 1998).

3 - Biological sampling at sea

Biological sampling by direct methods (trawl-survey) and the subsampling to perform analytical investigation on the population structure (e.g. cohort analysis), if well planned reflects what happens to the biomass at sea and to the demographic structure of the population.

The sampling conducted in the MEDIT-GRUND projects do not seems to satisfy the spatio-temporal requirements of an efficient sampling. This is due to lack of sufficient funding. Priority has been given to spatial coverage, but alternatively the sampling could be intensified temporally on target areas, leaving not covered other areas. This working hypothesis can be followed as there are already extensive investigation which give a good estimate of spatial-temporal distribution of resources (Atlante Ris. Ittiche Demers. Ital., 1997; Ardizzone *et al.*, 1998).

4 - The necessity of cohort analysis

For the target species, besides the calculation of catch per unit of effort, it is also essential to perform a cohort analysis base on subsampling. Moreover there is a need to develop, theoretically, the possibility to apply and extrapolate data and approaches (e.g. average fishing mortality rate F, average recruitment index R) to mixed stocks, thus simulating what actually happens in the commercial fishery. This issue deserve an in depth reflection by the scientists of the region and a series of ad hoc workshops.

5 - The total biomass as Reference Point

From cohort analysis the biomass at sea should be estimated ($(N_{t+1} – N_t) / Z\ t$) both in number and in weight, in order to obtain the total biomass (Catch + biomass at sea). It must be evaluated, if in the last ten years the total biomass, by stock and by mixed stocks, is increasing, decreasing or fluctuating around a mean value. This average decadal biomass value by area or basin can be assumed as REFERENCE POINT, a kind of fishing carrying capacity of the system, and be calibrated year by year with experimental and commercial catch data.

6 - Commercial catches

It is necessary to know the commercial catches by species and by basin, for a certain number of years (at least ten). If data are missing some estimate could be done. The organization which is responsible for collecting statistical data to the central administration in order to prepare the Triennial Fishery Plans, should make this data (by species and by area) available to the scientific community.

7 - VPA and professional fishing data

Applying VPA to commercial data an estimate of the biomass at sea could be obtained and adding to this the catch or the landing data an estimate of the total biomass could be reached, by year, by basin or by area and therefore fluctuations could be evaluated. The level of confidence and reliability is not high but better to have some kind of estimates than nothing. These estimates could be integrated by data on recruitment and on the average size of the stock.

8 - Total catches (landings), total biomass, C/f

It is important to evaluate agreements and disagreements between the different sources of data:

a) trends in total catches (from commercial data) by species, group of species, by basin or area.

b) trends in total biomass (from research data).

c) trends in C/f from research data by species, by group of species, by basin or area, year by year.

If C/f are decreasing while the other two (a and b) are constant, then there may be excessive fishing effort in the investigated area, thus the problem is not of resources availability but it affects the fishing enterprises because the resources are shared among too many boats (Atti Seminario Regolaz. Sforzo di pesca, 1994).

9 - Recruitment indices, total mortality rates (Z), and correlation with mean biomass

Some predictive suggestions at medium and short term could be obtained calculating year by year, the recruitment rate (average number of recruits / average number of adults) and the total mortality rate (Z from VPA) and correlating this with the environment on the one hand and with the fishing and intensity of effort in the investigated area, on the other (Zamboni *et al*., 1999; Zamboni *et al*., 2000).

10 - Technological parameters and fishing effort. Biodiversity and overexploited stock restoration

If the exploitation level is to be changed (increased or decreased), technological parameters of the fishing gear can be varied. Fishing gear interact between the man and the resources in a variety of way determined by their number (global effort), form and structure (e.g. selectivity), by the fishing time and by the local customs (i.e. only one trawl net for catching mixed stock) (Gruppo Metod. Statistic. GRUND, 1988).

Increasing the mesh size, increasing the size at first capture, a different design of the bottom trawl and other technological improvement do not alone restore an overexploited stock, especially if a recover of the biodiversity and environmental protection are sought. It is necessary to protect part of the sea, by means of artificial reefs (Ardizzone *et al*., 1994; Bombace, 1987, 1995,1996; Relini *et al*., 1998).

The proposal of Council Regulation dealing with measures for the sustainable exploitation of fishery resources of the Mediterranean, modifying EC regulations n. 2847 / 93 and n. 973/2001, is moving towards this directions and this is of great satisfaction for all the marine biologists who sustained the use of marine protected areas as instruments for fishery protection and management.

11 - Socio-economic aspects

Socio-economic aspects are to be taken into account, especially when special fisheries are dealt (e.g. small Gobids fishery in Northern Adriatic), or when the target are juveniles of species which in the adult phase are not of high commercial value (e.g. fish fry of sardine). Special fishing licences are to be issued with strict regulations in space and time.

12 - Fishery statistics and resources monitoring in Italy

There is an urgent double need to reform the fishery statistical system and the monitoring of resources. To evaluate the catch (landings) in a country like Italy, where there are many landing points, many species landed, many gears, many marine environments and many different size of the fishing enterprises, it is wrong to continue to use statistics by census. A sampling statistics is to be adopted as pointed out by the PESTAT programme of IRPEM-CNR of Ancona (Bazigos *et al*., 1984; Cingolani *et al*., 1986) and by MINIPESTAT del CNR of Mazzara del Vallo (Andreoli *et al*., 1995). Moreover sampling of commercial C/f besides scientific C/f must be performed.

Research sampling must allow also the analytical investigation on the population structure, which can be extrapolated to the professional fishery. We should therefore find a link between scientific evaluation and stock assessment data and fishery statistics, in order to comply with EC regulations 1543/00 and 1639/2001.

Conclusions

In conclusion the average biomass for a decade could be assumed as R.P.

This value can be corrected year by year, by means of a reliable stock assessment out coming from intense field sampling and analytical investigations.

There is a need of reliable fishery statistics followed by scientific monitoring on commercial boats (PESTAT model) and on scientific research vessels.

All this must become a permanent service which will improve the fishery sectors and comply to EC regulations.

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THE POTENTIAL USE OF INDICATORS, REFERENCE POINTS AND THE TRAFFIC LIGHT CONVENTION FOR MANAGING BLACK SEA FISHERIES.

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Abstract

The potential use of indicators and reference points in management of Black Sea fisheries is reviewed, and fisheries management rules using RPs and indicators are discussed, including their use in stock recovery plans. A review of possible approaches to setting RPs and indicators for Black Sea fisheries emphasizes the dynamic nature of recent ecosystem change. This means that models using steady state assumptions may not be appropriate, and an empirical approach to defining indicators is explored. Indicators of ecosystem instability and risk are also proposed based on rates of decline and extent of decline of commercial species characteristic of different habitats. The Traffic Light approach is illustrated as a means of following dynamic changes and gaining a broad perspective on events at the ecosystem level.

Introduction

This document discusses the use of indicators and reference points (RPs) as they are developing in the Black Sea region, but goes beyond the point at which most discussions on reference points end – by focussing on what reference points are used for, since in both the Black Sea and the Mediterranean, the first priority is to advise managers on how indicators and reference points may be used for management. If these can be placed in a multispecies context, so much the better, but the approach initiated in the Black Sea region places emphasis on using specific species as indicators of the health of particular environments. From Black Sea experience, the variety of models of multispecies interrelationships proposed have come to diverging conclusions, and modelling may not be an unambiguous first step to setting RPs for active management.

First, the term reference point as used in this paper represents a particular value of an indicator series commonly recognized to mark the state of the resource or environment. In ICES and many fisheries commissions, finfish reference points are commonly defined from the fitting of models. The author has suggested elsewhere (e.g. Seijo and Caddy 2000) that this is not necessarily the only approach, and more empirical approaches are emerging where data are scarce or ecosystem changes are dynamic (see also Caddy 1999 and Gilbert et al. 2000). Multispecies fisheries inevitably raise the problem of dealing with multiple indicators and their reference points. This issue is not touched upon in classical approaches, but is discussed here with respect to the traffic light convention and the need to display a wide range of ecosystem variables prior to beginning an ecosystem modelling exercise in a dynamic environment.

Indicators and reference points can be used in three main ways:

1) *Passive monitoring:* As a means of monitoring a phenomenon (e.g. overfishing, environmental change or stock condition) where immediate management action is not

necessarily tied to the value of the indicator. This may be referred to as a ‘passive’ management mode, for example, where quotas are not applied, or where year to year levels of effort cannot be regulated in real time.

2) *Active management:* involves using indicators as components of a ‘management rule’ such that when a limit reference point value is exceeded (Caddy and Mahon 1995), this supposes some action will be taken to restore the fishery to a safer condition. Stress is placed on the fact that determining reference points is not a ‘stand-alone’ scientific exercise – these points have little significance if not applied by management! An example of a management rule is the COMFIE-type rule suggested by ICES (1997), which defines two types of RPs, the so-called precautionary reference points B_{pa} and F_{pa}, and two limit reference points, e.g. B_{lim} and F_{lim}. These are generic reference points, in that they mark decision points of the rule, and can be derived either from models or based on well substantiated and accepted empirical values. There are problems in practice in applying a COMFIE style rule, discussed in Caddy and Agnew 2003 a), but the underlying concept is clear: indicators and reference points are needed to drive a management rule. What is more important, is that the fishing industry should understand the basis and utility of the reference points proposed.

3) *Stock recovery plans:* An extension of the use of a rule in routine management is its use in a stock recovery plan. Caddy and Agnew (2003a,b) review a range of fisheries where recovery plans have been used. This application presupposes another class of reference points defining not only the fishing mortality and biomass levels at which recovery plan actions should be triggered, but also the target reference point expressed in terms of the spawning potential or biomass at which the population is considered recovered. Defining targets for recovery of depleted stocks is in itself a worthwhile activity.

In summary, a focus on reference points implies that the infrastructure and internationally-agreed regulations are in place allowing some form of management rule to be applied. This currently appears not to be the case for most Mediterranean and Black Sea fisheries. Quota control is inexistent here, and mechanisms used to maintain fishing mortality within reasonable levels such as fleet capacity control, area and seasonal closures and technical measures cannot be applied easily in real time. Other approaches to formulating management rules need to be urgently considered than the conventional approaches which are built around quota control.

Use of indicators and reference points in active management

While there have so far been few examples of the use of reference points in active management in the Mediterranean and Black Sea, the Black Sea Commission is currently exploring the possibilities of using an approach to formulating a management rule which takes into account both impacts of fishing and environmental/ecosystem change. A past analysis of previous stock assessments (Prodanov et al., 1997), provides material that allows us first to explore several different approaches to monitoring stock changes and defining reference point values, and potentially incorporating these data sources into active management.

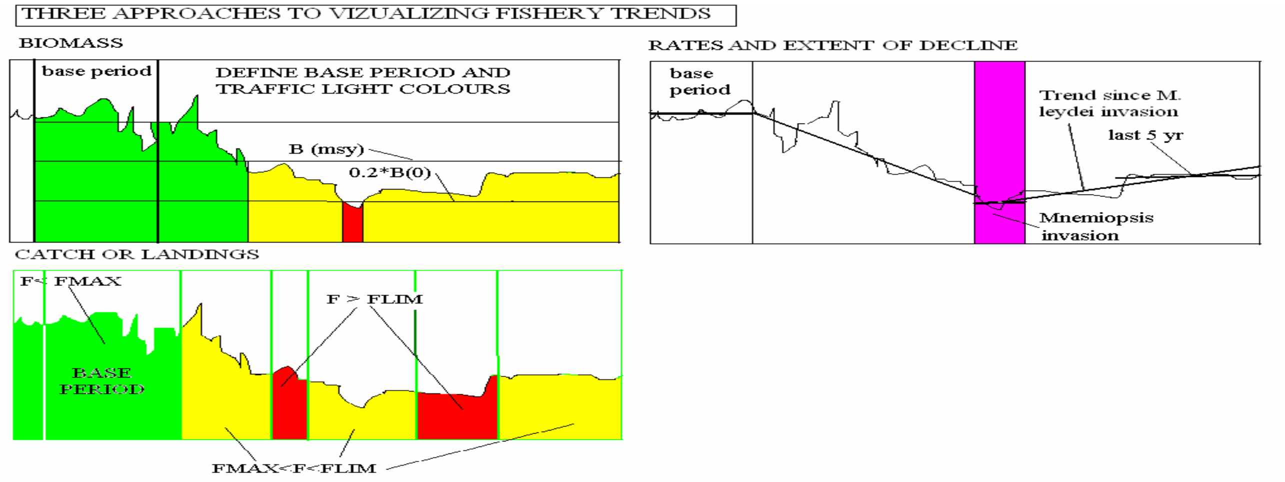


*Fig 1: Potential uses of indicator series for analysing changes in Black Sea fishery resources. (Top left): biomass levels expressed in traffic light colouration for two RP levels; B(MSY) and 0.2*B_0. (Bottom left): Landing trends coloured using annual estimates of fishing mortality based on retrospective analysis, segmented by estimates of F_{MAX} and F_{LIM} from yield/recruit analysis. (Top right): trends in landings or biomass for different time periods, before, during and after the peak of the <u>M.</u> <u>leydei</u> invasion.*

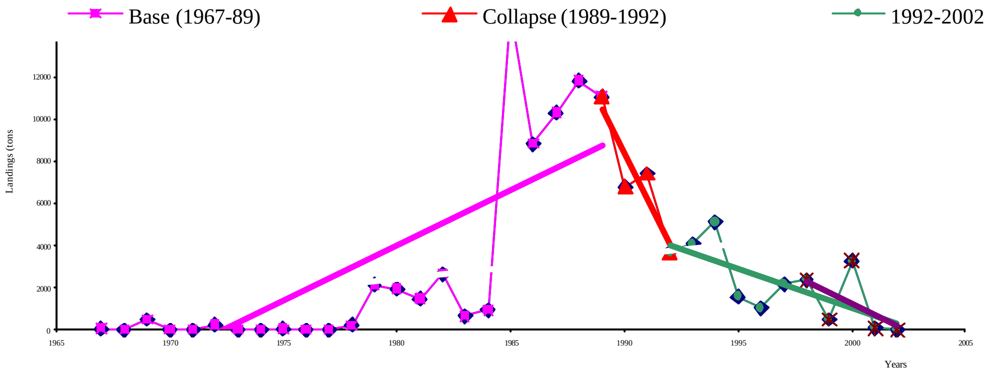
Use of trend analysis and the extent of decline in landings

Knowing that 1989-92 were the peak years of the *Mnemiopsis leydei* outbreak, one approach to defining indicators is to use this priori environmental information to segment data series using linear trends (Caddy et al. 2004); (Figs 1 and 2). Another is to fit long-term trends using polynomials (Fiorentini et al. 1997, and Fig. 3). Rather than just focussing on changes relative to recent periods when the stock may already have been depleted, a FAO (2001) working group examined criteria for listing endangered fish stocks by CITES, and stressed the importance of examining the 'rate of decline' over the short and long term, as well as the 'extent of decline' from earlier historical periods. As a result, two types of indicators were examined, those for:

a) Rate of decline (e.g. in biomass and catch)

b) Extent of decline from a benchmark or 'baseline period' (presumably when the ecosystem was in a 'safe' condition). In both cases, critical values for extent and rate of decline could be used to establish reference points that trigger stock restoration.

1) Chub mackerel



2)Anchovy

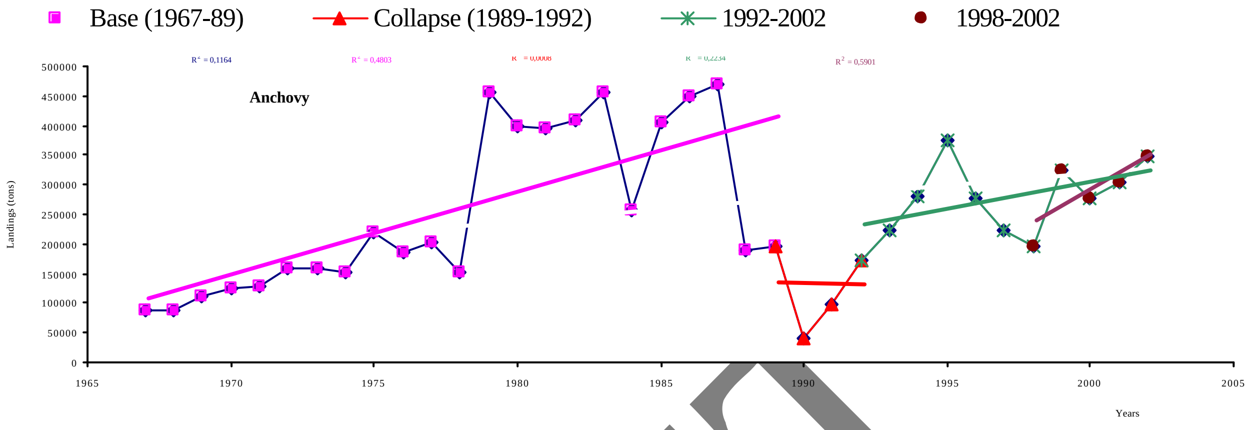


Fig 2: Segmentation of catch trends for a migratory and resident pelagic species, in light of the *__Mnemiopsis__* *invasion, showing similarities and differences.*

Evidently, chub mackerel and anchovy, with differing degrees and timing, both showed landing increases during an arbitrary 'base period' at the start of the data series, and for both, a serious drop in landings occurred during the main *Mnemiopsis* bloom, 1989-92. A subsequent recovery of anchovy landings has occurred over the last five years (but see Fig 7). In contrast, a continued long-term decline in landings occurred for chub mackerel, which dropped steadily to close to zero over the last five years on record. This comparison suggests that different ecological stresses applied to resident and migratory pelagic species. Table 1 extends this analysis to 14 important commercial taxa, and suggests that general ecosystem indicators could be the collective recent decline in landings (penultimate column), and the extent of decline (last column). Using these two criteria together, the mackerel (*S. scombrus*), bonito (*S. sarda*), Mugilidae and *Rapana sp*, emerge as priorities for management attention. Overall, the highest proportion of declining trends occurred in 1989-92, but a high ratio is also seen at the bottom of Table 1 for the last five years on record, suggest that if 'a recovery' followed the *Mnemiopsis* outbreak it may be short-lived.

Table 1: An indirect indication of the health of the ichthyofauna may be deduced from the following summary of trends and extents of decline shown by landings for 14 key species.

CATEGORY/ SPECIES	Baseline trend (before 1989)	Trend in in'Collapse yrs': 1989-92	Trend in 92-2002	Trend over Last 5 yr	Last 5 yr (1998-2002) landings as % of Baseline
Resident pelagic species					
Anchovy (*Engraulis*)	+ +	-	+	+ +	**136%**
Horse mackerel (*Trachurus*)	+ +	- -	-	+	**14%**
Sprat (*Sprattus*)	+ +	- -	+ +	-	**68%**

Migrants					
Mackerel (*S. scombrus*)	-	+	+	-	**2%**
Chub mackerel (*S. japonicus*)	+ +	- -	-	-	**42%**
Bluefish (*Pomatomus*)	+ +	-	+	+ +	**196%**
Bonito (*Sarda*)	0	+	+	- -	**5%**
DEMERSALS					
Turbot (*Psetta*)	-	-	+	+ +	**70%**
Whiting (*Merlangius*)	+ +	- -	-	-	**51%**
Spiny dogfish (*Squalus*)	+	- -	-	+	**32 %**
Mullets (*Mullus*)	-	+ +	0	- -	**164%**
Mugilidae	0	++	-	- -	**19 %**
Gobies	+	- -	+	- -	**139 %**
Rapana	N/A	N/A	+	- -	**13 %** (of '92-2002)
Ratio +ve /-ve	8/3 = **2.67**	4/9 = **0.44**	8/5 = **1.60**	5/9 = **0.55**	
KEY : (++): steep +ve slope (-) : negative slope. 0 : no trend.					

Although the trend analysis in the above table is only indicative, for a significant proportion of commercial species, landing trends were generally upwards in the first period, dropped seriously in 1989-92 when the *M. leydei* 'invasion' was at a peak (e.g. Mutlu et al. 1994), and showed a 'partial recovery' subsequently. However, when the last five years are considered separately, the apparent recovery looks less certain, except that landings of some species (anchovy, bluefish, gobies and Mullidae) seem to have staged a 'comeback', while a benthic species (*Rapana sp*), and from the lagoon and coastal group, the Mugilidae seem to be declining, as are immigrants such as the mackerels.

Although the single-species effects of fishing can be deduced from retrospective analysis of several Black Sea stocks (Prodanov et al. 1997), individual analyses do not help to integrate the whole ecosystem picture. Recent work within working groups of the Commission has tried to reconcile the effects of overfishing with environmental change. This includes nutrient runoff and the effects of the invasion by *M. leydei* on the pelagic biome. Such effects are complicated by the socio-economic consequences of fleet overcapitalisation. Up to now, coordinated action by coastal states to manage shared fishery resources is at an early stage, but is now being addressed by the Black Sea Commission. As a first priority, the approach is to list existing indicator series and possible reference points, with a view to further exploring their use in fisheries management rules. Annexes 1 and 2, though not referred to specifically in this communication, and Table 1 above, underline how conventional assessments of specific faunal components can also provide indicators of the health of particular environments or habitats.

Multispecies indicators and reference points

The theme of this meeting is the use of reference points in multispecies situations. Given the categorization of indicator use given in the Introduction, the immediate practical application of reference points in the Mediterranean and Black Sea areas is likely to be within a passive management or monitoring category. The theoretical and practical complications of modelling complex ecosystems as a basis for a management rule raises serious problems for fisheries managers, notably the need to reduce a range of complex data series to a decision rule. It is almost axiomatic that size selective processes of fishing, by reducing the mean size of the surviving fish in the sea, will reduce the mean trophic level, but so will nutrient runoff by inflating the base of the food pyramid. This illustrates the problem facing fishery managers in trying to translate a change in the level of a multispecies indicator into specific action.

If truncation of top predators has occurred through overfishing apical predators (e.g. Pauly et al. 1998), the appropriate reference points for applying management action might be single-species reference points for top predators. For inland seas, ecosystem change is also likely to have a strong bottom up component (Caddy 1993, de Leiva Moreno et al. 2000). If reduction of mean trophic level is due to enhancement of basic productivity, environmental controls on nutrient runoff might deserve priority. The issue of deciding what reaction is appropriate in response to changes in data-intensive multispecies indicators has to be dealt with early on. It has been evident since the 1970s that the dynamic nature of ecosystem change in the Black Sea makes 'steady state' models not very useful. It is also important to add information series measuring environmental conditions, since if stock-recruit models are used to define reference points, care must be taken that environmental conditions are not the main factors influencing recruitment success.

Contrasting views have been expressed and supposedly supported by different mathematical models of the Black Sea system (Table 2). The wide range of these suggests that modellers are influenced by preconceptions, if only in choosing the information to incorporate in their models, and this can be misleading if a range of variables have influenced events. Taking a broad scale approach to monitoring a wide a range of indicators is recommended prior to attempting a specific modelling approach, and Fig 9 shows that several critical factors influenced events, and the dominant factor may have changed between the 1960's and the start of the millenium.

Table 2: Some publications and models proposing different causal factors for recent changes in Black Sea ecosystems

Author	**Primary causes of ecosystem changes**	**Mechanism/ resulting effects**
Christensen and Caddy (1993)	Two static models of the Black Sea food web are presented: showing a) predicted effect of *M. leydei* on the pelagic ecosystem, and b) hypothesized effects of introducing *Beroe sp.* as a controlling predator on *M.*	After introduction of *M. leydei* in the early 1990s, it grossly dominated organic flows through the pelagic ecosystem, but given absence of predators, it short-circuited flows to the benthic bacterial loop. Introduction of *Beroe* was predicted

	leydei.	to reduce flows of material to detritus.
Mutlu et al. (1994)	*M. leydei* has a shorter generation time than *Aurelia* and small pelagics.	As a result it reduces food availability for these competing species at the same trophic level.
Kideys (1994)	Increased nutrient inputs led to abnormal phytoplankton blooms. Introduction of *M. leydei* was a key event that radically changed the ecosystem.	Competition of jelly predators with small pelagics for zooplankton led to the collapse of small pelagic stocks.
Aubrey et al. (1996).	Anthropogenic effects on the NW shelf near the Danube mouth are predominant due to nutrient runoff.	The interplay between high Danube nutrient loadings and Black Sea hydrological fronts provide opportunities for enhanced biological activity.
Daskalov (1999)	Recruitment of small pelagics is less dependent on parental stock size than environment variables (e.g. wind stress).	Recruitment of small pelagics in the Black Sea is predominantly influenced by environmental changes.
Berdnikov et al. (1999)	A specific Black Sea+Azov trophic model suggests that 'bottom-up' effects are predominant lower in the trophic chain. 'Top down' effects become only evident higher in the food pyramid.	Trophic competition between anchovies and *M. leydei*, rather than predation by the latter on anchovy larvae, was key factor for anchovy decline. Decomposition of unpredated *M. leydei* might destabilize bottom oxygen levels.
Rass (2001)	The reduction of cold spring flood outflow from Black Sea rivers due to damming rivers damaged water exchange.	This reduced the Rumelian stream in the western Black Sea formerly used by migratory species.
Gucu (2002)	A minimum role assigned to the *M. leydei* outbreak on the basis of a steady-state model.	Though eutrophication in the 1980s led to the outburst of jelly organisms, the decline in stocks was mainly due to overfishing.
Daskalov (2002)	Onset of industrial fishing and depletion of top predators (dolphins and migratory pelagics) in the early 1970's led to a trophic cascade affecting events for the next 30 yr.	Deleterious events are explained mainly by top-down release of predator control on small pelagics: increased nutrification is supposed to only increase the biomass of all components in the model.

Empirical approaches to deciding on reference points.

One school of thought (e.g. Gilbert et al. 2000, Seijo and Caddy 2000, Caddy, in press) suggests that since reference points need to be implemented in a fisheries rule, they must have credibility and be understandable to the fishing industry. Although the classical approach has been to generate RPs from yield or SRR models, the assumptions underlying ‘generic’ models may not fully apply, since they usually depend on an assumption of stability or equilibrium that is not tenable given the major ecosystem changes to the Black Sea that have certainly occurred. The various models applied to Black Sea resources and environments mentioned in Table 2, differ dramatically in the prime causes assigned to the ecosystem/fishery changes observed. It is clear from this that the axioms and the data used by each model have differed. In these circumstances, more reliance on a series of indicators reflecting changes at different levels in the ecosystem and its physical environment, without supposing a specific mechanism, seems a logical first step. Expert judgement will be needed to establish boundaries corresponding to serious risk of overexploitation or depletion, but all likely driving forces need to be taken into account.

Trenkel and Rochet (2003) and Rochet and Trenkel (2003) note that most multispecies indicators to date have been based on theoretical considerations. ‘Empirical’ population indicators such as mean length in the catch, the pelagic/demersal index (de Leiva Moreno et al. 2000 and Fig 3), the overall exploitation rate, the proportion of non-commercial species, and the proportion of piscivorous fish in the commercial catch (Caddy and Garibaldi 2000) were found to be statistically more reliable than estimates of exploitation rate or indicators based on food web modelling. A similar conclusion on trophic modelling was reached by Jennings et al. (2002) from stable-isotope analysis of food web components, and by Patterson (1992) for small pelagics. Mean trophic level and the pelagic/demersal ratio (Caddy 2000; de Leiva Moreno et al. 2000) have theoretical disadvantages as indicators in that they could be indicators of increased nutrient inputs as well as overfishing. An example of the use of trophic models for generating indicators is the huge effort put into developing the MSVPA model for the North Sea. This has been scientifically revealing, but has not resulted in it being used for fisheries management, but for estimating natural mortality rates in single species assessments. This in part because intrinsic assumptions on ration size are suspect given highly variable diets, and in part because of the extensive sampling required to fit multispecies models to a changing ecological situation in real time.

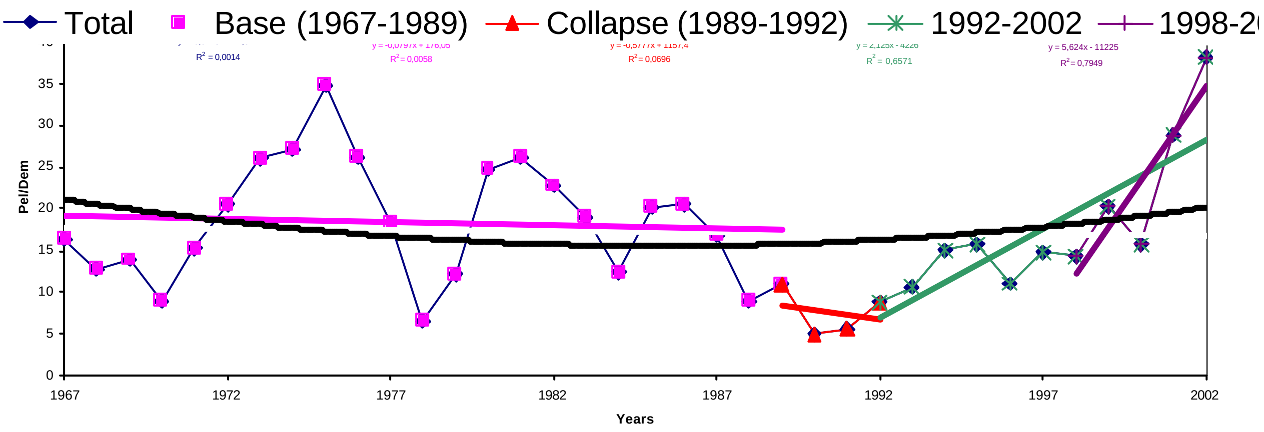
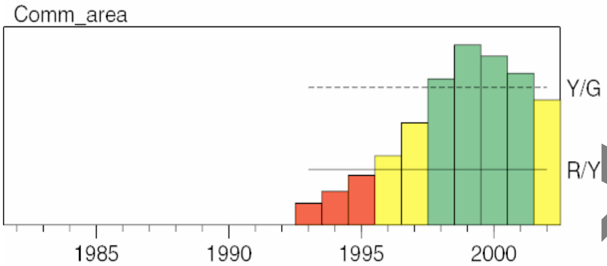


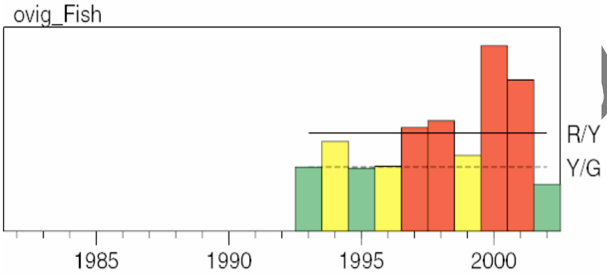
Fig 3: The pelagic/demersal index for Black Sea catches, and a polynomial fit for the whole time series, suggesting a decline to low levels in the 1980's, and some subsequent recovery after 1992.

Displaying multiple indicators – the traffic light approach

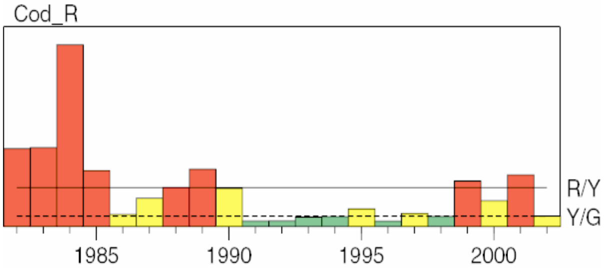
The example in Fig 4 illustrates a procedure for dealing with multiple indicators, including predator recruitment and biomass (Koeller et al. 2000). Several indicators in a traffic light array may measure various population characteristic such as biomass or mortality directly or indirectly. Judgements made from a knowledge of life histories, or from previous events in the same fishery, may also be appropriate. Such an approach has been referred to as a Traffic Light monitoring methodology.(Caddy 1999, Halliday et al. 2001). The following example for a North Atlantic shrimp fishery shows multiple indicators used in 'shrimp monitoring', based mainly on surveys and catch analysis in an essentially 'passive' management mode. Fig 4 shows for example, how expansion of the shrimp stock in the late 1990s coincided with a decline in cod (predator) biomass and recruitment, (probably both due to a decline in ambient temperature favouring *Pandalus borealis*, but not cod)**.**

Area (Km 2) fished by commercial fleet **Fishery on ovigerous females**





Cod recruitment (predator) **Indicator of predation**



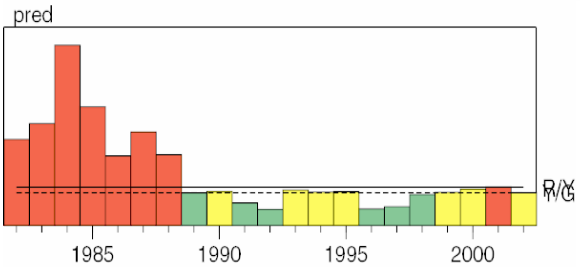


Fig 4: Extracts from a traffic light monitoring report for Northern shrimp (Pandalus borealis) by Koeller et al. (2000) shows 4 indicator series, segmented at the green-yellow and yellow-red boundary by biological criteria agreed to between resource experts and the fishing industry.

Sequence of development of indicators and reference points in fisheries

The classical reference point approach is to use one or two generic model-based indicators and their reference points (ICES 1997) as input to a fisheries management system, but these may not be easily estimated in absence of age-structured sampling. An alternate approach illustrated in Fig 5, is to develop a system of indicators and reference points for a range of population characteristics. This may also help to introduce biological realism into population monitoring. In developing indicators for Black Sea fisheries, one advantage is the lower species diversity than in the Mediterranean proper, but as shown by Fig 8, there are important driving functions operating in the Black Sea in addition to overfishing. Environmental changes associated with eutrophication and the impact of the introduction of exotic species have also affected the pelagic and demersal biomes (e.g. Zaitsev 1993).

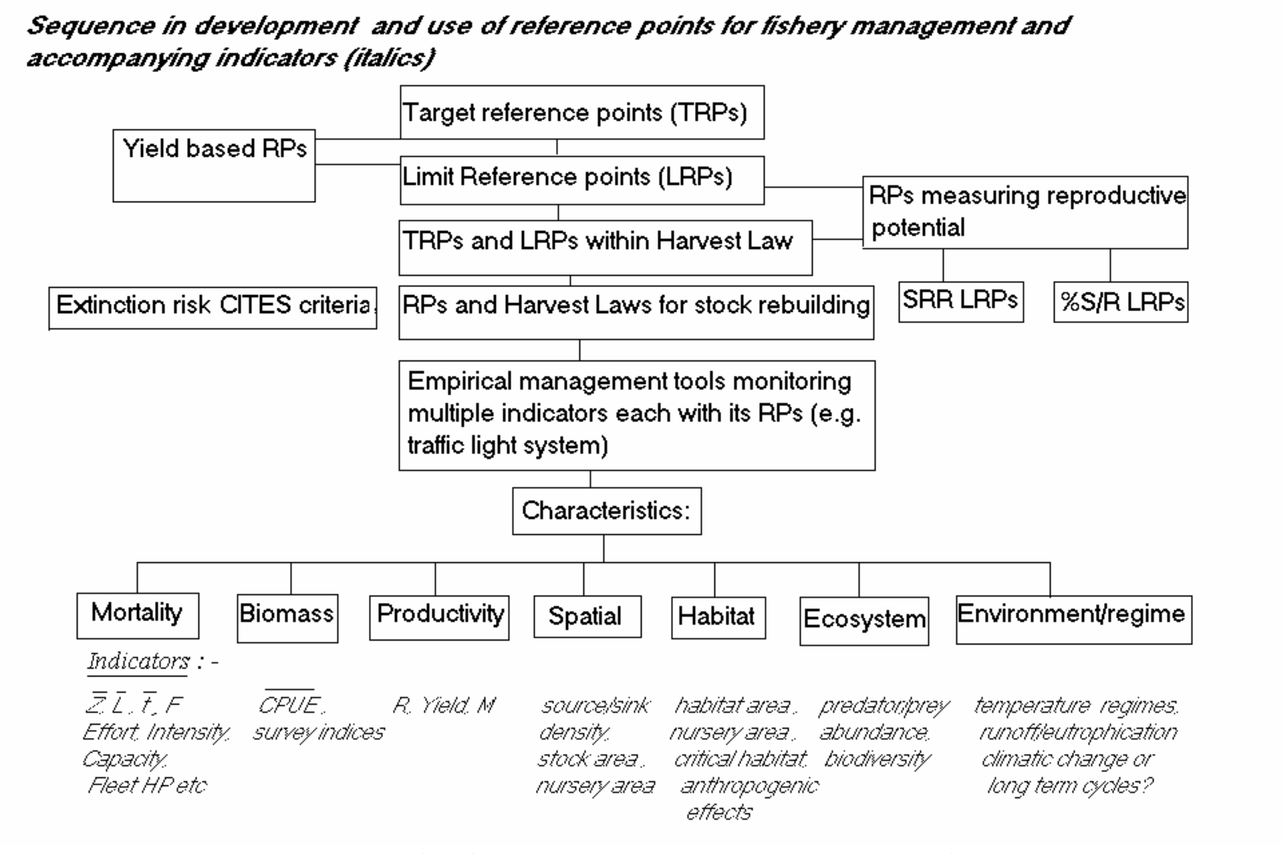


Fig 5: Evolution in the use of reference points (top downwards). Reference points based on MSY as a target were specified in the Law off the Sea, but in the 1990's emphasis moved to model-based LRP's, especially based on spawning potential, as marking limits when management action is mandatory to save the stock. The possible use of a broader range of ecosystem-based indicators suggested lower in the figure, raises the question of how to incorporate them into an advisory and decision-making framework.

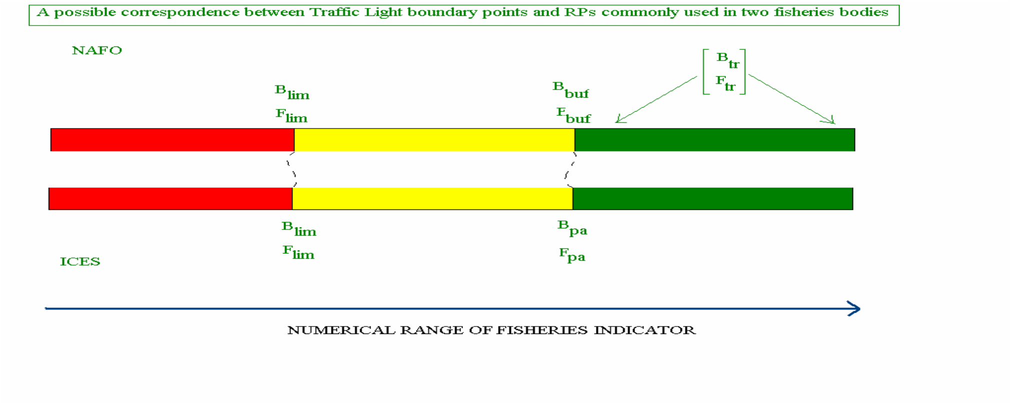
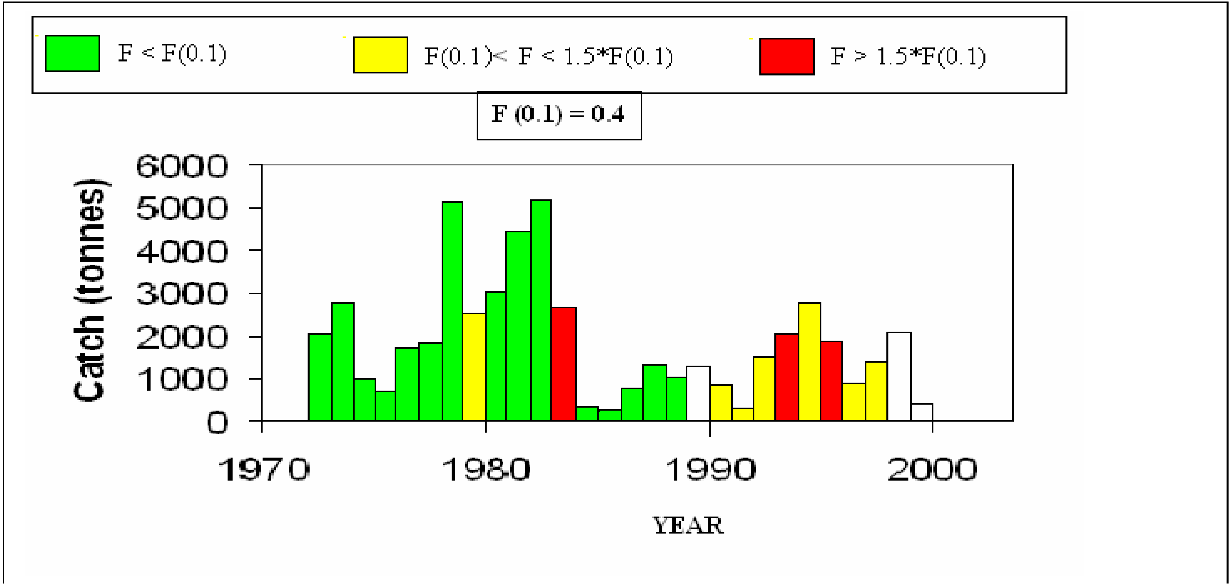


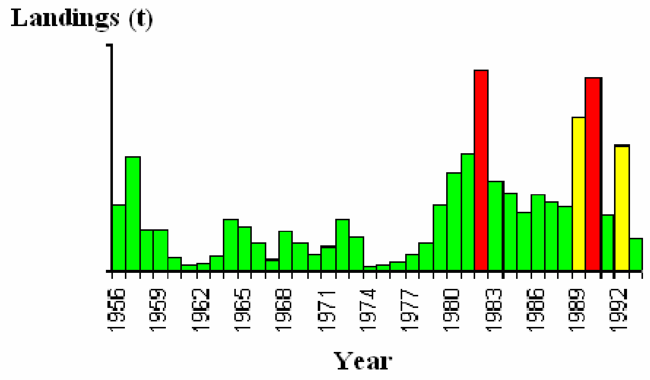
Fig 6: Illustrating how the colour convention used in traffic light colour charts can be reconciled with the precautionary and limit reference point criteria used in ICES and NAFO.

Choosing critical values for indicators

For an indicator to be useful, it must be possible from independent information or analysis to show that changes in indicator values correctly reflect changes in variables such as fishing pressure, biomass, or species composition which may not be easily measured directly, and the indicator must be easily understandable to non-technical audiences.

A form of graphical presentation was experimented with in Caddy (2002) and Caddy et al. (2004) which seems to provide insights into trends ongoing in the fishery. In the lower graph of Fig. 7 for sprat, based on retrospective analysis of annual age composition data (Prodanov et al.1997). traffic light colours have been assigned to annual catches, depending on the ratio of the annual fishing rate to the natural mortality rate. This assumes that for small pelagics, a fishing rate below that of the natural death rate is precautionary, given the high risk of death from natural causes that already applies (Patterson 1992). For turbot, an alternative approach assigned colour ranges based on an estimate of $F_{0.1}$ provided by Prodanov and Mikhailov (2003). Both cases illustrate that despite an apparent recent 'recovery' of landings in these fisheries after 1992, the exploitation rate also increased towards the end of the time series of landings, adding to the high current probability of overexploitation. This type of graph which combines two indicators in one, offers an efficient summary of the situation, and can be convincing when discussing research results with industry and non-technical fishery managers.





GREEN	YELLOW	RED
F < 0.5 M (M=0.95) i.e. F< 0.475	0.475 < = F< 0.712 (0.75M = 0.712)	F = > 0.712

Fig 7: Landing trends for turbot (above) and sprat (below) coloured using the traffic light approach and fishing mortality estimates obtained by retrospective analysis (Prodanov et al. 1997). Criteria for colour boundaries were decided based on comparing annual F values with an estimate of natural mortality rate (for sprat) and an estimate of F(0.1) for turbot by Prodanov and Mikhailov (2003) –(white signifies no data).

Empirical boundaries for indicators

Ideally, traffic light boundary points at the interface of green and yellow, and between yellow and red, should reflect a specific change in status, or segment the time series using values believed to represent important features of the population, or key events in the time series. However, in absence of data on specific boundary positions, the following empirical approach seems worthwhile for illustration purposes, and does not necessarily require such judgements. An empirical population distribution function (pdf) is created from a time series of values (as in Fig 8), first ranked, and then the range of the variable divided equally into thirds, each assigned a different colour value.

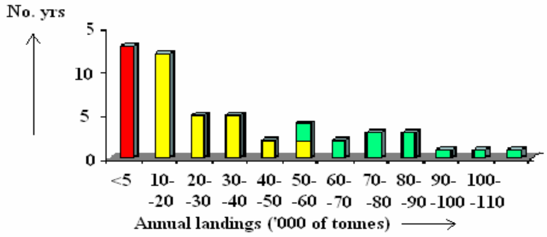


Fig 8. Dividing a time series into three colour categories (sprat landings) – Note: 'red' in this case does not represent uniformly unfavourable conditions, as the initial years of the fishery when effort is low are also classified as 'red'.

This approach allows a large number of indicators to be displayed together. Such an empirical approach to monitoring changes in a wide variety of indicators is shown in Fig 9.

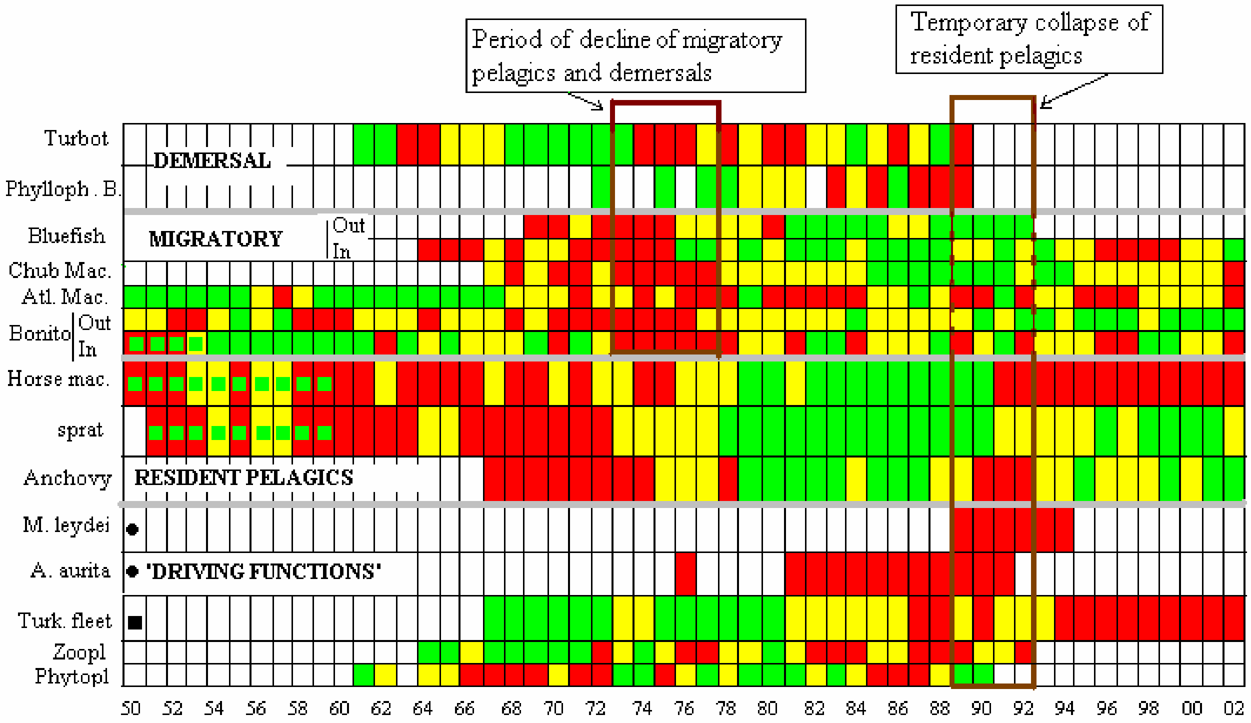


Fig 9: Traffic light illustration of trends in multiple indicators using the procedure in Fig 8. For commercial species, indicators are landings, but a low 'red' value in the 1950's probably does mean overexploitation, and early pelagic catches are stamped with a green square. 'Red' may be associated with overexploitation late in the series when fleet size is higher. This 'arbitrarily scaled' traffic light plot is mainly useful for seeing correspondences between indicators. Several postulated driving functions are grouped together at the bottom of the figure, and include phytoplankton and

zooplankton biomasses, 'abundant' jelly predators are coloured 'red' where recorded as such). For the estimate of Turkish fleet size, unlike the other indicators, red implies a high value.

Although it would be desirable to divide the range of an indicator into zones corresponding to safe, uncertain and dangerous conditions by boundary values tested by experiment or experience, this may not readily achieved. Dividing the observed range of an indicator into three zones, each containing close-to-equal numbers of years, seems a useful first step in making comparisons between indicators prior to formal ecosystem analysis or modelling. In Fig 9, for most indicators shown, the procedure in Fig 8 was followed. Several relationships seem to emerge from the multiple comparisons within this figure that deserve further investigation:

1) Phytoplankton standing crop in the 1960s to early 70s was relatively low, but rose in the 1970's-80's presumably due to eutrophic effects associated with hypoxia of Black Sea shelves (Zaitsev 1993). Landings of 'resident' pelagics (anchovy, sprat and horse mackerel) increased in the 1980's and planktonic standing stocks declined. Anchovy, and horse mackerel (and to a lesser extent, sprat) catches dropped drastically at the end of the 1980's, coinciding with the *M. leydei* outbreak, and zooplankton levels also declined. Sprat and anchovy catches later recovered, but horse mackerel catches did not, nor did migratory pelagics until towards the end of the time series, though mackerel catches are still low. Blooms of jellyfish *(A. aurita)* and later and more drastically, the introduced ctenophore, *M. leydei*, led to competition with anchovy for food (Berdnikov et al. 1999). The impacts of this jelly predator bloom decreased after the mid-1990's, and recovery of anchovy production occurred (perhaps due to introduction of *Beroe ovata*, a predator on *M. leydei* into the Black Sea?). The effective fleet size fishing pelagics rose to still higher levels after anchovy recovery.
2) High phytoplankton abundance (green) also coincided with declines in catches of migratory pelagics (early 1970's), (though catches outside the Black Sea also declined over the same period, suggesting that this decline was not specific to the Black Sea). (The 'Out' indicators for migratory pelagics in the above figure consists of summed catches of all countries in the eastern and central Mediterranean except Turkey and Black Sea States, and is a proxy for stock abundance in the Aegean and Marmara Seas and eastern Mediterranean. Unlike the Black Sea fishery however, catches of bonito outside in the Mediterranean rose towards the end of the time series, suggesting that poor Black Sea catches after the 1980s were not due to a decline of the entire Mediterranean + Black Sea bonito resource. Timing of the rise in phytoplankton production seems to coincide with a reduced entry of migratory pelagics into the northern Black Sea after 1980, suggesting the hypothesis that migratory pelagics may have reduced their immigration through the Bosphorus to the Northern Black Sea after 1980; perhaps due to environmental deterioration and/or changes in current patterns (See Rass 2002).
3) Other ecological instabilities became evident in the early to mid-1980's with progressive disappearance of the *Phyllophora* (red algae) fields in the NW Black Sea. This was suggested during the GFCM meeting on Black Sea fisheries in

1993 as due to lower water transparency and bottom water hypoxia caused by organic debris from high planktonic production. This deterioration in benthic environments would have affected demersal resources, since decimation of macrophytes (*Phyllophora*) and reduction in shelf resources (turbot) tend to occur synchronously in Fig 9. The coincidence of increased jellyfish (*A. aurita*) abundance, and rises in landings of resident pelagics, presumably are also results from increased system productivity. The general increases in fishing capacity of the Turkish pelagic fleet towards the end of the time series, which is currently much the largest in the Black Sea, presumably also imposed higher exploitation rates on the pelagic resources.

4) Although deductions based on Fig 9 cannot exclude any particular mechanism, it is difficult to see how the collapse of migratory pelagics and demersals in 1973-77 led directly to the collapse of small resident pelagic populations in 1989-92, when both *Mnemiopsis* introduction and dramatic growth in capacity of the pelagic fleet occurred in the intervening years.

This complex sequence of events with its hypothesized multiple effects and interactions can only be presented as hypotheses, but Fig 9 illustrates that the sequence of events cannot be easily explained as simply a cascade effect resulting from a release in predatory pressure, (though some cascade effects undoubtedly applied earlier in the time period). The significant increase in human ‘predation’ over the time series has probably more than made up for the decimation of natural predators. *Mnemiopsis* should be regarded as a competitor more than a predator for the resident small pelagics, and occupies much the same trophic level. As suggested by some authors, perhaps this was allowed to dominate the ecosystem niche due to overfishing, which could have released predatory control on the zooplankton. Further discussion of the possible hypotheses and their different consequences for management are discussed in GESAMP (1995). It seems that a graphical approach displaying all available indicators may be a useful first step to more intensive analysis and modelling of ecosystem indicators.

Using SRR data to establish indicators

Cohort analysis has rarely been applied in the Mediterranean, but more frequently so in the Black Sea. Another traffic light approach is to segment SRR data into poor, average and good years for reproduction based on data on spawning stock biomass and recruitment from cohort analysis (Fig 10). Years were divided into good (green), medium (yellow) and poor (red) levels of recruitment, used an index, the log ratio of recruitment/spawning stock biomass using data from Prodanov et al. (1997 - table 48). The data points were divided into three segments containing equal numbers by lines through the origin. This procedure is similar to that of Sissenwine and Shepherd (1987) for obtaining the RPs, F(low) to F(high). Contrary to their assumption of stock equilibrium however, Fig 10 for Black Sea sprat shows that recruitment success is to a large extent independent (or even inversely related to) spawning stock size. It is interesting that sequences of poor and good years generally occur closely together, and the highest productivity years often correspond to low spawning stock biomasses (SBBs), though whether environmental conditions as well as stock biomass is the critical factor is not clear.

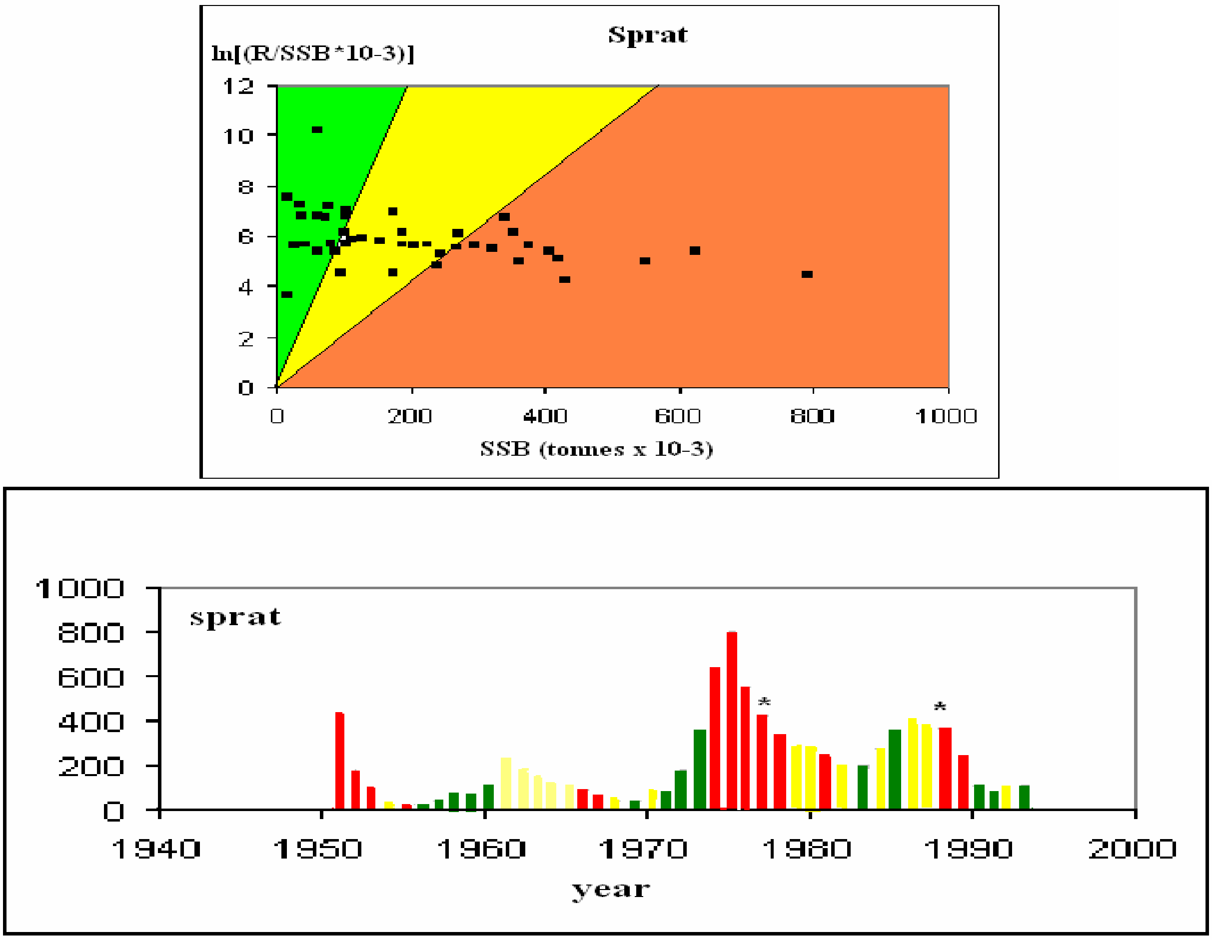


Fig 10: (Upper) Segmenting SSR data for Black Sea sprat into three zones with equal numbers of points per zone. (Lower) Time sequence of sprat biomasses show resulting low, medium and high levels of recruitment success by red, yellow and green respectively. The two asterisks mark periods when jellyfish (first Aurelia then Mnemiopsis) outbreaks occurred, though reliable quantitative data for the time duration over the whole period of time is not available, which is unfortunate.

Use of a fisheries control rule employing indicators and reference points

Here, we discuss a simple management rule where there are two pairs of reference points marking a sharp jump from one 'phase' of the fishery to another (Fig 11, & upper Fig 13). This is realistic, since for most fisheries data, the 'noise' is too high to justify a management model dependent on precise estimates of indicator values.

Fig 11 represents such a management rule, illustrating the two legal criteria used in the US to manage stocks and define which stocks must be restored. Two triggers for action are specified: a stock can be '**overfished**' (i.e. the resource is depleted) and/or '**overfishing**' is currently occurring (i.e. the current level of F is too high, whatever the stock size). These two risk factors are treated independently along the two axes below, each with it appropriate RPs, such that routine management and stock rebuilding emerge as two components of the management procedure. A hypothetical time series of events during rebuilding is illustrated in Fig 12 (from Caddy and Agnew 2003a)

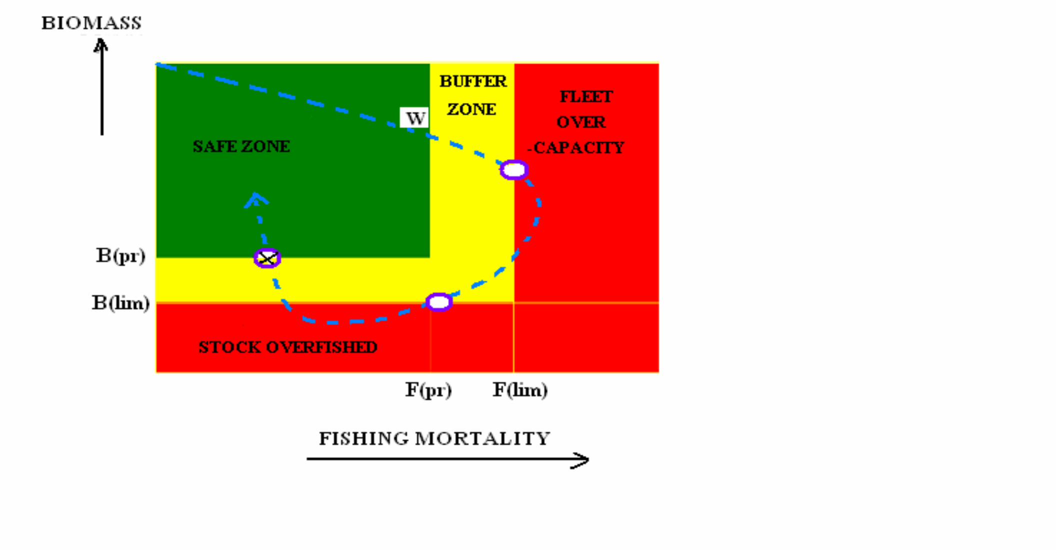


Fig 11: Visualization of a fisheries control law such as the Magnuson-Stevens Act of the US Congress in traffic light terms. Here, precautionary reference points for biomass (B) and fishing rate or capacity (F), mark the transition from safe (green) to uncertain (yellow) conditions, and limit reference points from yellow to red (dangerous) conditions. The trajectory for the fishery (blue) triggers a regulation limiting effort at the first open circle, and at the second, a rebuilding plan is initiated further cutting fishing effort, until at the crossed circle, the fishery returns above the precautionary rebuilding target B(pr) : (modified from Caddy 2004-in press).

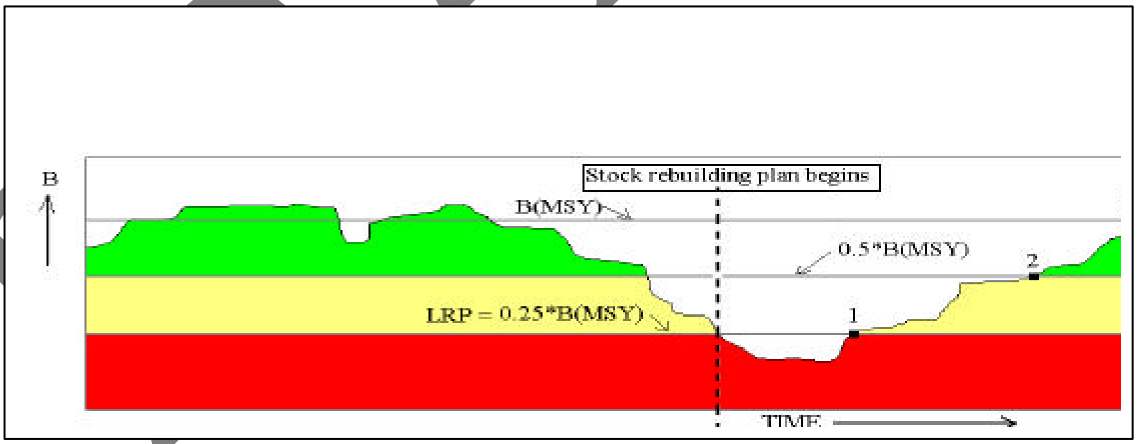
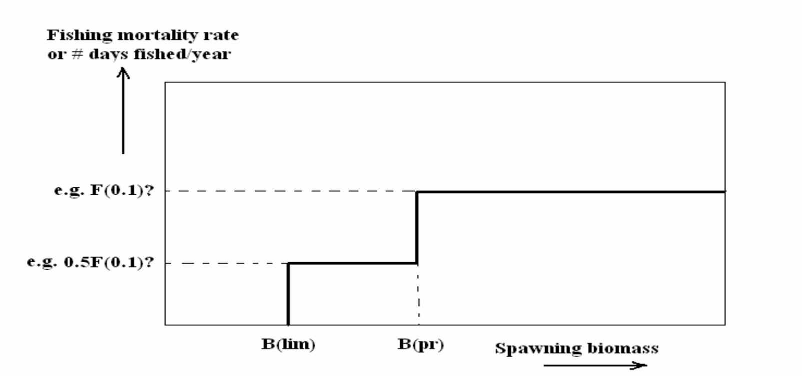


Fig 12: Possible use of a management rule for stock rebuilding. The biomass corresponding to a quarter of that needed to support extraction of MSY, initiates a compulsory recovery plan which continues until the biomass is once again above B(MSY). (Points 1, 2 and 3 are 'way stations' serving to identify stock status during rebuilding).

The conventional type of management rule presented in Figs 11 and upper 13, uses only two indicator series to manage the stock: (spawning) biomass and fishing mortality rate. Because such a rule is based only on two indicators, it risks missing the ecosystem and environmental dimensions of the management problem. Another approach is being considered for management of snow crab fisheries in the Gulf of St Lawrence is potentially a biologically more precautionary type of control rule: in that case, if the percent of ‘soft-shell’ unmarketable crabs exceeds a critical value, local fisheries are closed: (but the same principle could be use with other biological data):

a) Control points may be, but do not necessarily have to be, derived from a model; they can incorporate arbitrary values for biomass and % harvest as long as there is industry consensus.
b) A supplementary biological rule can be incorporated for local fishing areas, such as the closure of a sub-zone of the fishery when over a fixed proportion juveniles are included in the weekly catch as judged by on-board observers. A rule which incorporates ‘redundancy’ in this way, ensures that if the conventional control rule fails, there is a back-up based on an independent data series.

The potential application of this type of approach to the Mediterranean and Black Sea requires that capacity and license numbers be controlled, some measure of fishing mortality be estimated annually, and regular surveys of biomass be maintained. However, Fig 13 (lower) adds to this hypothetical F-Biomass rule a second management dimension, calling for an immediate reduction of fishing effort (e.g. a restricted number of days fished/week) if some other criterion is infringed. This second criterion under the management rule may apply to local grounds if observers on fishing vessels detect that rapid stock declines of critical life history stages are observed, where there are high incidental catches of protected species, or where damage to critical habitats is occurring.



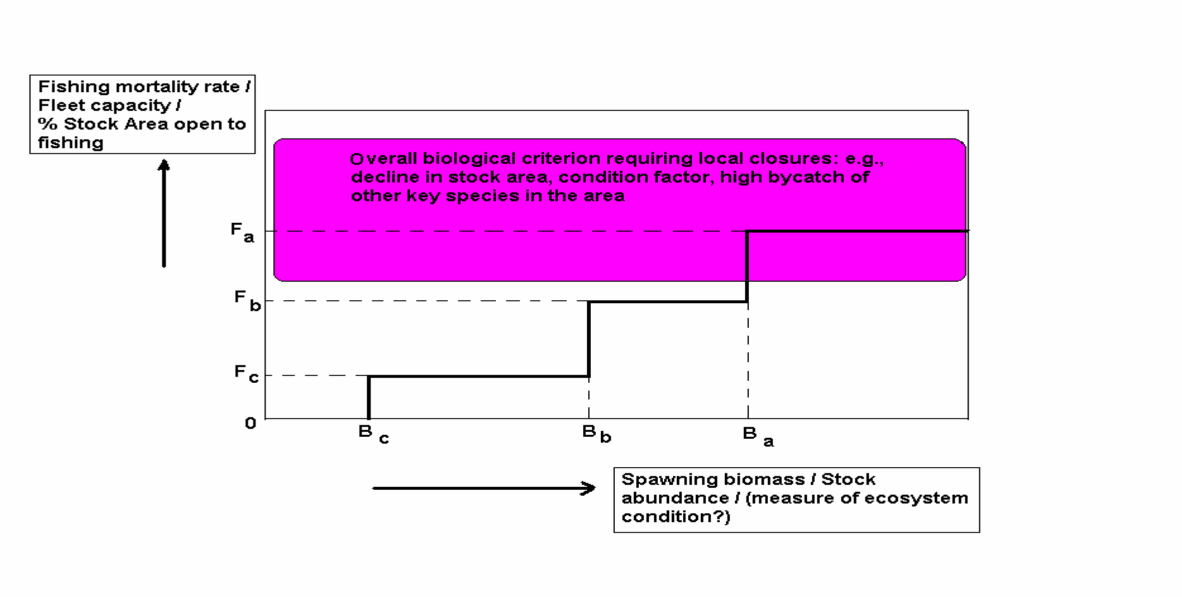
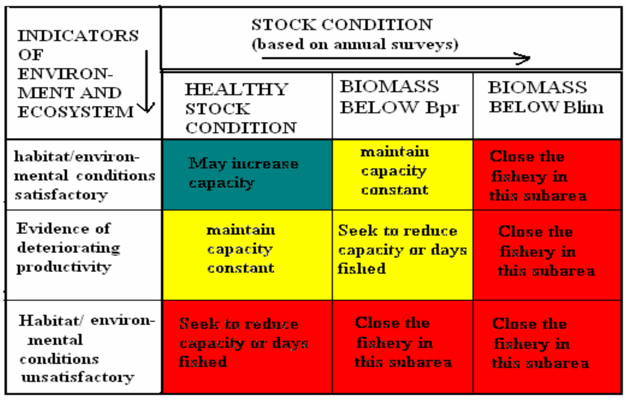


Fig 13: Two types of management rule. Upper: A simple management rule constrains fishing mortality at B_{pr} and B_{lim} when spawning biomass drops below specified reference levels. Lower: A further constraint is added to the upper type of rule, which may be based on biological or social constraints (some examples are given in the lower figure), and where B_a, B_b and B_c are levels of biomass decided in consultation with experts and industry representatives.

Alternative types of fisheries control rule are being considered by the Canadian ‘Fisheries Resource Council’. The first considers how to improve the critical interface between ‘Science’ and managers receiving research advice where a lack of comprehension often occurs. Instead of suggesting a specific quota, in the approach shown in Fig 14, ‘Science’ is requested annually to place each stock in a ‘box’, based on an evaluation of its current productivity and stock size. For each of these boxes, the appropriate management action is pre-specified, thus discouraging discretionary action by managers under this type of management rule. A modification of the original approach which assumed quota control, is suggested in Fig 14 for fisheries where capacity and area fished are the two control variables used, as in the Mediterranean and Black Seas. The second approach is to design a rule which reacts progressively to restrict impacts on the stock as a function of te number of indicator series which are showing ‘red’ (Caddy 1999), or by the use of a more sophisticated rule using the same traffic light indicators, but based on fuzzy logic criteria (e.g. Halliday et al. (2001).



INDICATORS OF ENVIRON-MENT AND ECOSYSTEM ↓	STOCK CONDITION (based on annual surveys) →		
	HEALTHY STOCK CONDITION	BIOMASS BELOW Bpr	BIOMASS BELOW Blim
habitat/environ-mental conditions satisfactory	May increase capacity	maintain capacity constant	Close the fishery in this subarea
Evidence of deteriorating productivity	maintain capacity constant	Seek to reduce capacity or days fished	Close the fishery in this subarea
Habitat/ environ-mental conditions unsatisfactory	Seek to reduce capacity or days fished	Close the fishery in this subarea	Close the fishery in this subarea

Fig 14: A management control matrix' for use in the communication of scientific advice to fisheries managers.

Discussion

The need to determine reference points for a fishery is evident, but this paper notes it is necessary to bear in mind that LRPs are primarily for use in fisheries control rules, and makes some suggestions as to the type of rules that might apply in the Mediterranean and Black Sea fisheries. Establishing indicators and reference points for Black Sea fisheries and ecosystems requires that the very dynamic changes of this system, and that the multiple factors driving the ecosystem be taken into account. Although landings data can provide some indications as to the dramatic events that have occurred over the last 3 decades, using fishing mortality estimates from retrospective analysis show that the increase in landings after the early 1990s resulted from an increase in capacity as much as from stock recovery, though some modest recovery does seem to have occurred. In addition to overcapacity, the ecosystem has responded to dramatic changes resulting from nutrient runoff, and the introduction of exotic species to the pelagic biome which have radically changed the ecosystem. An improvement in environmental conditions recently has been hypothesized; anecdotal information suggests that reductions in nutrient runoff may have been occurring, and a new species, *Beroe ovata*, which preys specifically on *Mnemiopsis*, has been introduced. Approaches to modelling following different hypotheses of causative factors underlying ecosystem change have inevitably led to differing conclusions as to the 'prime' factor leading to ecosystem change. This makes a 'model-based' approach to determining indicators and reference points controversial at this point. The approach that seems to be established by the Commission is to following trends in productivity of those species that best represent the different biological communities and habitats of the Black Sea.

Plotting changes in a wide range of empirical indicators simultaneously after classifying their dynamic range using an empirical Traffic Light methodology, helps to formulate possible hypotheses, and illustrates that different factors have influenced the ecosystem through time. The key to immediate progress in upgrading the ecosystem will be agreement on fisheries management rules, but above all, their application! Several approaches to the use of indicators and reference points in such rules are suggested. Empirical reference points can be envisaged that seek to avoid those indicator values that applied during the dramatic ecosystem changes in 1989-92. When setting a realistic target for restoring this badly damaged ecosystem, it seems logical to aim as closely as possible, to restoring the baseline mesotrophic conditions that applied prior to 1989.

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Annex 1: Decisions made on indicators at the workshop on demersal resources in the Black Sea and Azov Sea, of the Black Sea Commission; 15-17 April 2003, Sile, Istanbul, Turkey.

At this technical meeting of scientists of member States of the Black Sea Commission, agreement was reached by national representatives on actions that need to be taken in developing indicators for selected commercial species and habitat/ environmental indicators. Apart from reporting responsibilities on catches which apply to all harvested species, as an initial approach, it was decided that:

1) it would be better for the Commission to recommend a focus on collection of research indicators for a limited number of species and population characteristics, while allowing the possibility to revise the number of indicators subsequently if needed.
2) Some ‘keynote species’ should be decided on as a focus for maximum effort of cooperative studies.
3) Country responsibilities for studies on keynote species are not confined to those countries currently taking the major catch – other countries should contribute data.
4) Suggesting a ‘lead role’ in studies for any country does not imply any special preference as to allocations, quotas etc in any future management regime. The focus of research is simply a function of local availability of data or research resources for studies on the species and its research interest.
5) Some other activities (e.g. on environment, biodiversity, sturgeons) are being discussed in other components of the Black Sea Commission activities, and by CITES, hence coordination is implied by listing them in the following tables in which fisheries sector may not wish to take lead role.

Annex Table 1: Possible annual indicators for consideration for measuring different characteristics of Black Sea fish stocks. (Indicators may be values as shown, or made a ratio to some optimum or limiting value).

Characteristic/indicator	Answering question:	Units
Environmental indicators		
Indicators of nutrient runoff/availability	Basic productivity conditions	ppt nitrates, phosphates etc. in river runoff/surface waters
Bottom hypoxia (seasonal) mean value/extent - Conc. (ppt) hydrogen sulphide/other contaminants	Shelf hypoxia, especially in summer is negative for shellfish/demersal fish	Levels of O_2/H_2S (ppt) and of contaminants (various)
Wind speed/direction	?? upwelling ??	Km/hr
Stock biomass	Amount fish stock available as a basis for setting quotas.	
CPUE/ survey BT		Catch/tow/ tonnes

Exploitation rate	Current rate of stock removal	μ - (dimensionless)
Fishing effort	Indicator of risk of mortality by fishing	days fished summed after calibrating by vessel fishing power
Fleet capacity	As above, but also an index of investment in the fishery, and used for allocation negotiations	Summed horsepower or tonnage
Species productivity		
Annual recruitment	Successful annual replenishment of stock	Numbers *10^{-6}
Mean size-at-age	Indicator of growth rate (for younger ages)	cm
Condition factor /oil content (anchovy)	Indicator of feeding success	dimensionless/ %
Prey biomass	Measures food availability	tonnes
Popl'n fecundity/abundance of mature fish	Measures potential spawning contribution of stock	Numbers eggs/mature fish
Species range	An indicator of environmental suitability	Use GIS methods to plot and estimate surface areas occupied
Community productivity		
Planktonic productivity	Basic food available to food web/source of demersal hypoxia	Water sampling or remote sensing for chlorophyll A?
Species diversity	Changes in basic biodiversity	May measure ecological changes
Pelagic/demersal biomass ratio	An increase in the indicator may imply stress on demersal biome	dimensionless
Mean trophic level	An index of both top-down truncation of food web, and bottom up enrichment	dimensionless

Annex Table 2. Ecosystem/habitat focus for indicators (some overlap with biodiversity group – shown in italics)

(Indicator objectives: determine state of habitat/key resource using biomass, range, quality)

Indicator category	**Indicator needed**	**Lead country(ies)**	**Comments**
Critical habitats			
- Lagoons and inshore	Mugilidae biomass, distribution, size structure, demography.	All	Local resources. But suggest a cooperative focus on lagoon restoration, including aquaculture applications. (A

	Mussels (range, quality of meats) Venus clam (range)	**All(not Russia)** All	range of environmental data collected, incl. bottom water oxygen, resource contaminants). Cooperative studies/programmes of contamination Tech. Consultation on artificial reefs. Indicator of clean bottom conditions.
- Shelf areas	Turbot (See table 2) Rapana (range, catch rate) **Anadara cornea**	(Lead role: Russia) Russia, Turkey, (Lead role: Georgia)	Needs cooperative management. Local.
Gobies	Demography, cpue, range	Russia, (Lead role: Ukraine).	Indicator of oxygenation of northern shelf.
Red mullet	Demography, cpue,range	All (Lead role Turkey)	Indicator of clean bottom conditions.
- Pelagic biome	- Sprat, anchovy, horse mackerel (See table 2) - *Phytoplankton (Chl a density-seasonal)* - *Zooplankton (catch/tow seasonal)* - *Jelly predators (catch/tow-seasonal)*	All *All(Lead role: Russia)* *All (lead role-Russia?)* *Russia*	Coordination of survey programmes. *Remote sensing imagery* *Egg+larval+oceanographic plankton surveys* “ “ “ “ Organize oceanographic study of environmental impacts on stock migrations/abundance, and on impacts of pelagic conditions on demersal benthic biome.
- Conservation of threatened or endangered species.	- Sturgeons - Shads, Black Sea salmon.	Danube countries, Russia, Georgia, Ukraine + Turkey (lead role Romania) *Salmon:Lead role Georgia, Turkey. Shads: Lead role*	Needs cooperative management. (Cooperation with Black Sea sturgeon initiative of CITES).Cooperative studies promoted with other agencies. Collect information on stocks and spawning rivers and environmental quality.

	- *Dolphins (bycatch, range, sightings)* - Rays (range) - *Phyllophora*	*Romania+ other Danube countries.* All All Ukraine	ACABAS, Bonn Convention linkages. Compare current catch, size, distribution to historical data. Monitor area of seaweed beds.
Migratory species a) between Mediterranean – Marmara <-> Black Sea b) Between Azov +Black Sea.	Mackerel, bluefish, bonito (range, demography, migration routes) Migration of species between Azov and Black S.	(Lead role Turkey) – not Russia, Georgia Esp. Russia, Ucraine	Transboundary and highly migratory stocks. (Cooperate with GFCM & ICCAT to establish range of species, genetic identity, stock status in Mediterranean, Aegean, Marmara, Black Sea). Develop index of abundance of migratory species into/out of Azov?
Consider meeting to discuss validity/optimal approach to conserving genotypes through hatchery enhancement (e.g. turbot, sturgeon).			

Annex table 3. Keynote species focus for priority actions as indicators
(Indicator objectives: determine state of habitat/of key resource using biomass, mortality, growth, fecundity, range, quality)

Indicator category	**Indicator needed**	**Lead country**	**Comments**
Pelagic			
- Anchovy	Catch, cpue, age/size structure of catch, biomass, age or size structure; F, condition factor (seasonal), oil content, mean size at ages 1,2., popln. fecundity, range	All (Lead Turkey)	Needs cooperative management. Currently most catch taken by Turkey, but as important keynote species, some special sampling needed from other countries – especially for range/distribution. Needs management plan/control effort and/or TAC/alocations. *High exploitation rate for small pelagics may promote Mnemiopsis blooms and affect zoo/ phytoplankton abundance, possibly affecting shelf hypoxia through detritus loop in ecosystem.* *Orhganize modelling workshop to*

			consider relations between key biota and linkages between pelagic and benthic habitats.
- Sprat	Catch, cpue, age/size structure of catch, biomass, age or size structure, F, condition factor (seasonal), mean size at ages 1,2., popln. fecundity, range	All. (Lead Bulgaria)	Needs cooperative management. Currently most catches taken by Ukraine, Russia and Bulgaria. Important by catch of whiting. Needs management plan/control effort and/or TAC. *(See comment in italics for anchovy)*
- horse mackerel	(As above)	All. (Lead Turkey)	Needs cooperative management.*(See above comment in italics for anchovy)*
Demersal/benthic shelf			
- Turbot	Catch, cpue, age/size structure of catch, biomass, age or size structure; F, condition factor (seasonal), mean size at ages 1,2., popln. fecundity	All (Lead Turkey)	Needs cooperative management. Need for common B.S. stock assessment. Decide on common objectives in a management plan (limited entry, TAC, common fishery regulations, closed areas, gear types allowed etc). Organize meeting to discuss management plan.
- Whiting	Catch, cpue, age/size structure of catch; biomass, age or size structure; F, mean size at ages 1,2., popln. fecundity.	All (Lead Romania)	Needs cooperative management. Management of this species needs coordinating with that of sprat fishery.
Dogfish	Demography, cpue, range	All (Lead Turkey)	Slow-growing, low fecundity species – indicator of fishing pressure.
General			Considered desirable to prepare a small booklet for each key species with key information, assessments.

Annex table 4. Fishery ecosystem indicators

(*Objective: locate indicators from fisheries data base that reflect health of whole ecosystem)*

Indicator category	**Indicator needed**	**Lead country**	**Comments** (1st 3 indicators await compilation of all species data).
Pelagic/demersal ratio	Indicator (biomass and/or catches) of pelagic resources and benthic+ demersal resources	All	A general indicator of health of demersal biome is a low value for ratio.
Piscivore/planktivore ratio	Indicator (biomass and/or catches) of food	All	A general indicator of degree of exploitation of the ecosystem.

	web exploitation.		
Mean trophic level	Indicator of degree of truncation of food web and/or eutrophication using all ecosystem components.	All	A general indicator of anthropogenic impact on food web.
Marine protected areas and (seasonal) closed zones	Proportion of national sea areas included in closed areas.	All (Secretariat to organize)	Use GIS approach to document areas.
Develop historical atlas of species ranges, critical habitats, nursery/spawning areas.	Document ranges/densities (if possible for every decade since 1950's).	All (Secretariat to organize)	Use common GIS approach to document in a fisheries Atlas together with ranges of all known species. (Coordinate with FAO FIGIS for methodologies and data). – workshop on GIS/Atlas of fisheries?
Document distribution fleets/fishing areas by main ports.	Show this in fisheries Atlas.	All (Secretariat to organize)	Add boundary agreements/ fleet distribution data to fisheries Atlas.
Effect of gear on key species/habitats.	Monitor bycatch dolphin in gill nets/ Monitor distribn. of dredges/trawl gear & their impact on bottom oxygen levels.	All	Monitor gillnet bycatch of critical species. Consider regulations to reduce impacts of fisheries on migrration routes (e.g. avoid blocking straits needed for migration – allow fishing in straits and migration corridors only a few days per week?). Closed areas/seasonal (summer) closures for bottom gear to avoid hypoxia. Experimental studies in summer of effects of hydraulic dredging on local oxygen H2S levels/incidental mortalities.

Annex Table 5. General indicators of socio-economic nature (*This table is considered incomplete and items marked *require specialised socio-economic inputs). (Objectives: determine impact of sector, its economic health, capability of regulation and research)*

Indicator category	**Indicator needed**	**Lead country**	**Comments**
Fleet numbers by category/target species of vessels licensed nationally to fish in 2002.	Description vessel, owner, current level of activity	All (Secretariat to organize)	A common database of vessels operating in 2002, and existing but inactive vessels which are licensed to fish.

Number of days fished per year by gear type/category/ target species. (Use EC vessel/gear categorization).	Total effort = sum (HP*days fished per year). This is an indicator of fishing pressure. Data may be obtained through sampling a known proportion of fishing trips/vessels using a standard and agreed sampling scheme.	All (Secretariat to organize)	Suggest a log book with common format be used to collect national data, and/or standard port interview form. It will be necessary to develop a sampling frame prior to developing approach to port visits.
Fleet tonnage/shelf area	An indicator of fishing pressure.	All (Secretariat to organize)	This is a general indicator of fishing intensity, and should be calculated separately for main gear types.
*Employment in fisheries sector. (primary/secondary) as proportion of population size. (Also indicate proportion of private sector participation, and info on cooperatives).	An indicator of effort, but also of interest in sector.	All (Secretariat to organize)	A general indicator of relative importance of fishery sector and how it is organized. Organize meeting to discuss how the fishery sector is organized in member countries.
*Fish consumption/per capita	An indicator of market demand.	All (Secretariat to organize)	Need to know consumption of local catch, but also imports/exports from and to countries outside the Black Sea area.
National regulations for keynote species	Document approaches to regulation, and Monitoring, Control and Surveillance.	All (Secretariat to organize)	Harmonizing regulations for keynote species is necessary first step to harmonized Black Sea management measures under the Commission.
MCS capability	Document number of staff dedicated to controlling adherence to regulations.	All (Secretariat to organize)	One suggestion here is to consider introduction of VMS (Vessel monitoring system) using satellite ‘black box’ on industrial scale vessels. (Suggest to organize meeting of national MCS personnel to discuss harmonization of MCS procedures).
Research coordination	List scientists/programmes by key species/problem areas. Document research vessel programmes and objectives.	All (Secretariat to organize)	This will be necessary for planning cooperative programmes. Calibration/coordination of survey methodologies will be needed.

*Consumer inputs NGO's	Define priorities for national requirements for fish Identify national groupings concerned with ecosystem and fishery resource health	All (Secretariat to organize)	Sponsor consumer surveys of fish consumption. Organize meeting of conerned NGO's to look at ecosystem priorities, and strategies to harmonize approaches with use of 'fish for food'. (See UNCED priorities). Look at sport fishing organizations and possible roles in conservation of habitats/resources.

APPLICATION OF BIOLOGICAL REFERENCE POINTS TO THE BATHYAL FISHERY IN THE MEDITERRANEAN SEA: DIFFICULTIES IN THE MONOSPECIFIC APPROACH

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Abstract: Biological reference points F_{max} e $F_{0.1}$ have been applied to the bathyal trawling in the Ionian Sea (Mediterranean Sea). In this fishing, *Aristeus antennatus* and *Aristaeomorpha foliacea* are the target species, *Plesionika martia*, *Phycis blennoides* and *Helicolenus dactyloperus* are the marketable by-catch species and *Caelorhynchus caelorhynchus* is a discard species. The behaviour of the "yield per recruit" model has been examined changing the age of entry corresponding to the use of trawl net with mesh size of 40 and 60 mm in the codend and to the age of smallest mature specimens and age at first maturity. Results show that F_{max} is extremely variable and very difficult to be estimated considering that yield per recruit curves often show an asymptotic trend over a wide range of F values. Moreover, although marked differences in the yield per recruit curve behaviour were observed, $F_{0.1}$ values calculated for the different species were more conservative and informative than F_{max}. Excluding *P. martia*, the actual F values were higher than $F_{0.1}$ showing a clear overfishing condition for these resources.

Keywords*: bathyal trawling, stock assessment, reference points, F_{max} and $F_{0.1}$, Ionian Sea, Mediterranean Sea*

Introduction

The red shrimps *Aristeus antennatus* and *Aristaeomorpha foliacea* are the target species of the bathyal trawl fishing in the Ionian Sea (Mediterranean Sea). This fishery includes the presence of some commercial by-catch species, such as the crustacean *Plesionika martia* and *Nephrops novegicus* and the finfish *Merluccius merluccius, Micromesistius poutassou, Phycis blennoides, Helicolenus dactyloperus,* as well as discarded species like *Caelorhynchus caelorhynchus, Nezumia schlerorhynchus* and *Hymenocephalus italicus* (D'Onghia *et al.*, 2003). Even though the two red shrimps can represent up to the 58.60% in weight and the 66.15% in the economical value of the total catches (Carlucci *et al.*, 2003), the commercial by-catch species can often make up very important sources of economic incomes for fishermen and the discard species often constitute noteworthy biomass thrown out to the sea.

As any other kind of fishery in the Mediterranean Sea, the bathyal trawling grew up in time without the application of any metric estimation of the stock dynamics (growth, recruitment and mortality) in a "biological reference" fashion or of an adaptive management strategy which takes into consideration the multispecificity of the catch itself. At the present, this trawl fishery is managed controlling the fleet capacity, applying some administrative measures like the fishing closed season and by the regulation of the mesh size in the codend (40 mm, legal mesh size in the European Mediterranean Sea).

Considering the great fluctuations in the abundance of the red shrimps, it becomes necessary a suitable exploitation rate for these two resources that, in this particular case, can be also consistent with the multispecific reality in the fishing grounds.

In this context we examined the behaviour of the "yield per recruit" model (Beverton and Holt, 1957) for six species characteristic of the bathyal fishery in the Ionian Sea. In particular, for each of the considered species, the changing of the biological reference points F_{max} e $F_{0.1}$ (Beverton and Holt, 1957; Gulland and Boerema, 1973) has been examined by the age of entry into the exploited stock and the fishery mortality rate trying to point out how a monospecific approach is difficult to be applyied in a multispecific fishery contest. In this respect, a further objective of this paper is that to provide a contribution to the debate on the assessment and management of the biological resources in the Mediterranean Sea. In fact, the authors in the same scientific context give further contributions either to the use of models for the individualization of biological reference points (Giove *et al.*, present volume) and to a different methodological approach in the resources management (D'Onghia *et al.*, present volume).

Materials and methods

The "yield-per-recruit" model (Beverton and Holt, 1957) allows to derive a un biological reference point (b.r.p.) which is the fishing mortality rate (F_{max}) corresponding to the maximum yield obtainable from an exploited stock. F_{max} is a syntethic index usually used as an approximation of F_{MSY}. However, considering that often F_{max} overstimates F_{MSY}, a more conservative b.r.p. ($F_{0.1}$), the fishing mortality rate corresponding to the 10% of the slope of the yield-per-recruit curve at the origin (Gulland and Boerema, 1973), is often precautionally considered.

In this viewing we examined the behaviour of the yield per recruit model for six species characteristic of the bathyal trawling in the Ionian Sea (Mediterranean Sea). The red shrimps *Aristeus antennatus* and *Aristaeomorpha foliacea* are the target species, *Plesionika martia*, *Phycis blennoides* and *Helicolenus dactyloperus* are the by-catch species and *Caelorhynchus caelorhynchus* is a discard species. In particular, the changing of the biological reference points F_{max} and $F_{0.1}$ has been examined for the females of each species considering different ages of entry in the exploited stocks. The ages of entry into the exploitation correspond to the use of a mesh size in the codend of 40 mm (legal mesh in the European Mediterranean Sea) and 60 mm, as well as to the age of the smallest mature specimen and to the first maturity. In Tab. 1 the values of the paramethers of the yield per recruit model for each species (Ragonese *et al.*, 1995; D'Onghia *et al.*, 1996, 1998, 2000, 2003; Maiorano *et al.*, 2002; Tursi *et al.*, 2003; Carlucci *et al.*, in press) have been reported. For each of the species the actual fishing mortality rate (F) estimated considering the use of a 40 mm mesh size has been compared with the corresponding values of F_{max} and $F_{0.1}$ obtained from the model.

Results

The yield per recruit values and the reference points corresponding to the differents species considered are reported in Tabs. 2 and 3. For all the species an increase in the yield values by increasing the age of entry into the exploited stock was observed.

Considering *A. antennatus*, both the yield values estimated in F_{max} and $F_{0.1}$ are quite similar to those obtained for the fishing mortality F equal to 0.35. However, comparing F with these reference points it comes out an optimal condition and a slight overfishing using the calculated values of F_{max} and $F_{0.1}$, respectively. The overexploitation decreases if the age of entry increases.

In *A. foliacea* the asymptotic trend in the yield per recruit curves prevent the choice of an univocal value of F_{max}. Furthermore, a marked "growth overfishing" condition appears in this shrimp considering that the actual fishing mortality is about 3 times the value of $F_{0.1}$ calculated using a 40 mm codend.

With regard to the by-catch commercial species, *P. martia* showed an underexploitation condition considering that the 40 mm mesh is selective for this shrimp allowing specimens close to the first maturity size to pass throughout (D'Onghia *et al*., 1998).

In *P. blennoides* and *H. dactylopterus* the yield per recruit values estimated for the actual fishing mortality rates using the 40 mm codend resulted quite similar to those corresponding in $F_{0.1}$. However, considering the actual values of F it comes out a clear condition of overexploitation for both species. Finally, a condition of overfishing was also shown in *C. caelorhynchus*. The fishing mortality for this discarded species resulted about 3 times greater than the value of $F_{0.1}$ calculated for a 40 mm codend.

Discussion and conclusions

The yield per recruit model points out that the species caught in the bathyial trawl fishing react to the exploitation in very different patterns. In fact, even considering just six species the analisys showed pronounced differences in the yield per recruit curves. In this context, F_{max} results very variable and difficult to be extimated considering that in crustacean species the curves generally showed an asymptotic trend mostly increasing the age of entry into the exploited stocks. The biological reference point $F_{0.1}$ resulted more informative allowing the comparison with the yield per recruit corresponding to the actual fishing mortality rates extimated for each species and the 40 mm codend.

Considering equal yields, the present values of F in all species are greater than $F_{0.1}$ (with exception of *P. martia*) pointing out an evident condition of overfishing which can be reduced by increasing the age of entry.

The present results show the difficulty in detecting an univocal biological reference point using a monospecific approach, considering that the bathyal trawl fishing in the Ionian Sea, even if targets the red shrimps *A.antennatus* and *A. foliacea*, is often carried out with hauls at different depths in order to catch other resources (*P. longirostris, N. norvegicus, M. merluccius*). In this context, the monospecific approach proposed by the stock-oriented Beverton and Holt model, even if provides information on the exploitation condition of each species, does not allow to indicate clear management measures for the resources as a whole. However, the simplicity of the model and the limited knowledges of the stochastic phenomena in the population dynamics, drove the authors to the use of the same model modified for a multispecific approach (Giove *et al.*, present volume).

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Tab.1 - Values of the yield per recruit model parameters used for each of the species considered in the Ionian Sea.

Parameters	***A. antennatus***	***A. foliacea***	***P. martia***	***P blennoides***	***H. dactlylopterus***	***C. caelorhynchus***
Linf. (cm)	7,89	6,98	3,05	70,30	28.76	12,76
k (yr^{-1})	0,22	0,45	0,44	0,13	0,18	0,13
to (yr)	-0,23	-0,18	-0,05	-0,77	-0,84	-1,06
Winf. (g)	160,77	94,52	17,32	1876,12	437,59	371,13
M	0,34	0,48	0,69	0,28	0,33	0,35
age I capture (40 mm sMS)	0,97	0,47	1,07	0,30	0,34	0,61
age I capture (60 mm sMS)	1,39	0,62	1,79	1,42	2,11	2,51
age smallest mature	1,26	1,30	1,49	1,81	4,13	1,57
age I maturity	2,07	2,04	1,56	3,51	5,46	3,83
age smallest specimen	0,26	0,09	0,45	0,04	0,11	0,25
age max	9,20	5,77	4,30	30,00	25,00	10,00

Tab. 2 - Yield per recruit values and biological reference points for the different species considered in the Ionian Sea.

Aristeus antennatus

Age of entry	Y/R@Fmax	Y/R@$F_{0.1}$	Y/R@F	Y/R_{Fmax} *vs* Y/R_F	$Y/R_{F0.1}$ *vs* Y/R_F
0,97	6,25	5,92	6,19	1,01	0,96
1,39	6,93	6,52	6,93	1,00	0,94
1,26	6,71	6,33	6,71	1,00	0,94
2,07	8,04	7,47	7,86	1,02	0,95

Age of entry	$F_{maxY/R}$	$F_{0.1}$	F	F_{max} *vs* F	$F_{0.1}$ *vs* F
0,97	0,34	0,22	0,35	0,96	0,63
1,39	0,40	0,25	0,35	1,15	0,71
1,26	0,38	0,24	0,35	1,08	0,69
2,07	0,56	0,31	0,35	1,59	0,89

Aristaeomorpha foliacea

Age of entry	Y/R@Fmax	Y/R@$F_{0.1}$	Y/R@F	Y/R_{Fmax} *vs* Y/R_F	$Y/R_{F0.1}$ *vs* Y/R_F
0,47	6,43	6,10	5,80	1,88	1,11
0,62	6,85	6,49	6,44	1,74	1,02
1,30	8,66	8,01	8,66	1,60	0,91
2,04	10,03	8,92	9,44	1,68	0,91

Age of entry	$F_{maxY/R}$	$F_{0.1}$	F	F_{max} *vs* F	$F_{0.1}$ *vs* F
0,47	0,53	0,35	0,96	0,47	0,32
0,62	0,59	0,38	0,96	0,55	0,35
1,30	1,01	0,53	0,96	1,01	0,48
2,04	2,32	0,73	0,96	2,40	0,64

Plesionika martia

Age of entry	Y/R@Fmax	Y/R@$F_{0.1}$	Y/R@F	Y/R_{Fmax} *vs* Y/R_F	$Y/R_{F0.1}$ *vs* Y/R_F
1,07	1,19	1,11	0,94	1,12	1,07
1,79	1,40	1,24	0,86	1,00	0,75
1,49	1,34	1,21	0,91	1,12	1,05
1,56	1,36	1,22	0,90	1,02	0,84

Age of entry	$F_{maxY/R}$	$F_{0.1}$	F	F_{max} *vs* F	$F_{0.1}$ *vs* F
1,07	1,35	0,71	0,44	2,34	1,44
1,79	4,00	1,06	0,44	4,62	1,20
1,49	2,28	0,90	0,44	2,37	1,44
1,56	2,56	0,94	0,44	3,66	1,29

@ = corresponding to

Tab.3 - Yield per recruit values and biological reference points for the different species considered in the Ionian Sea.

Phycis blennoides

Age of entry	**Y/R@Fmax**	**Y/R@F$_{0.1}$**	**Y/R@F**	**Y/R$_{Fmax}$ *vs* Y/R$_{F}$**	**Y/R$_{F0.1}$ *vs* Y/R$_{F}$**
0,30	31,40	29,84	21,32	3,10	1,38
1,42	37,95	35,85	33,16	2,43	1,07
1,81	40,52	37,94	37,38	2,15	0,89
3,51	51,48	46,29	51,45	2,41	0,92
Age of entry	**F$_{maxY/R}$**	**F$_{0.1}$**	**F**	**F$_{max}$ *vs* F**	**F$_{0.1}$ *vs* F**
0,30	0,16	0,11	0,44	0,37	0,25
1,42	0,22	0,14	0,44	0,50	0,33
1,81	0,25	0,15	0,44	1,20	0,48
3,51	0,48	0,21	0,44	7,89	0,70

Helicolenus dactylopterus

Age of entry	**Y/R@Fmax**	**Y/R@F$_{0.1}$**	**Y/R@F**	**Y/R$_{Fmax}$ *vs* Y/R$_{F}$**	**Y/R$_{F0.1}$ *vs* Y/R$_{F}$**
0,34	10,54	9,98	8,11	3,19	1,26
2,11	15,07	13,83	15,00	2,41	0,92
4,13	19,02	16,03	17,53	2,52	0,89
5,46	19,50	15,22	15,96	2,90	0,94
Age of entry	**F$_{maxY/R}$**	**F$_{0.1}$**	**F**	**F$_{max}$ *vs* F**	**F$_{0.1}$ *vs* F**
0,34	0,21	0,14	0,52	0,41	0,27
2,11	0,43	0,22	0,52	0,82	0,42
4,13	1,67	0,34	0,52	2,33	0,58
5,46	-	0,42	0,52	-	0,81

Caelorhynchus caelorhynchus

Age of entry	**Y/R@Fmax**	**Y/R@F$_{0.1}$**	**Y/R@F**	**Y/R$_{Fmax}$ *vs* Y/R$_{F}$**	**Y/R$_{F0.1}$ *vs* Y/R$_{F}$**
0,61	4,45	4,10	3,48	1,61	1,15
2,51	6,65	6,58	6,64	1,35	0,94
1,57	5,54	5,09	5,22	1,39	0,96
3,83	7,89	7,75	7,60	1,49	1,00
Age of entry	**F$_{maxY/R}$**	**F$_{0.1}$**	**F**	**F$_{max}$ *vs* F**	**F$_{0.1}$ *vs* F**
0,61	0,25	0,15	0,55	0,51	0,35
2,51	0,51	0,28	0,55	1,12	0,65
1,57	0,34	0,20	0,55	1,59	0,83
3,83	1,00	0,49	0,55	2,40	0,99

@ = corresponding to

SYSTEM COMPLEXITY AND UNCERTAINTIES IN THE ASSESSMENT: WHAT REFERENCE POINTS?

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Abstract

Authors report some observations on the deep-water rose shrimp, *Parapenaeus longirostris* and the red shrimps, *Aristeus antennatus* and *Aristaeomorpha foliacea*, with the aim to highlight the non equilibrium conditions of their populations and the uncertainties in the assessment giving raise the discussion on the need of management options which overcome the application of conventional stock-oriented models and the relevant reference points. The authors propose a management approach in which "monitoring working groups", composed by governments managers, scientist, representative of the fleet and fishermen, operate in a process with the aim to obtain real-time information to promote the institution of time-area closure in short time. The time-area closure (even temporary and flexible in space) should be adopted primarily in relation to the recruitment peaks and nursery areas. Such management measures should be integrated with the adoption of a larger mesh size in the cod-end used in deep-water trawling in order to realize a management system robust to uncertainties, suitable for multi-species management and that meets ecosystem objectives.

Keywords: *fishery complexity, stock assessment uncertainty, reference points, management measures, Mediterranean Sea.*

Introduction

The complexity in the management of marine biological resources is due to the manifold variables concerning environmental phenomena, technological aspects and socio-economic problems as well as the uncertainties in the assessment of stochastic processes concerning the exploited populations (recruitment, mortality etc.) (Hilborn, 1997; Cochrane, 1999; Stokes *et al*., 1999; Gislason *et al*., 2000; Stergiou, 2002). Indeed, Cochrane (1999) reported among the causes of the problems in the fisheries management: the enormous biological uncertainty; the existence of multiple and conflicting objectives in the fisheries; the dominance of socio-economic objectives over attempts to utilize resources sustainability; the failure to involve the major stakeholders in meaningful decision-making. Thus, the scientific questions concerning the management of the fishery resources should not be dealt with the classical "hypothesis testing" method in which the variables involved in the study phenomenon can be constantly checked. This type of complex themes, such as global change and other environmental topics, should be studied according to the "post-normal science" methodologies (Funtowicz and Ravetz, 1993) characterized by two main aspects: the uncertainty and a set of values coming from a plurality of perspectives. In this respect, fishery science often cannot provide univocal management options but only indications that should be integrated together with other knwoledge forms (e.g. from socio-economic science) and the contribution of all the stakeholders involved in the fishery system (Hilborn, 1997).

In this paper, authors starting from some observations on three important Mediterranean demersal resources caught in the Ionian Sea, the deep-water rose shrimp (*Parapenaeus longirostris*) and the red shrimps *Aristeus antennatus* and *Aristaeomorpha foliacea*, highlight the non equilibrium conditions of their populations and the uncertainties in the assessment giving raise the discussion on the need of management options which overcome the application of conventional stock-oriented models and the relevant reference points.

Materials and Methods

Data on the deep-water rose shrimp (*Parapenaeus longirostris*) and the red shrimps *Aristeus antennatus* and *Aristaeomorpha foliacea* were collected as part of national and international study projects carried out in the Ionian Sea from 1985 to 2003 (GRUND and MEDITS). Methodological details of these three studies are reported in Relini (1998) and Bertrand *et al*. (2002).

In *P. longirostris* CPUE (kg/h), density (N/km^2) and biomass (kg/km^2) indices were computed for each GRUND survey carried out from 1985 to 2000. Density (N/km^2) and biomass (kg/km^2) indices were also calculated considering two sub-areas with different fishing effort: one along the Apulia coast and the others along the Calabrian coast. Considering the 1985-2000 period, the CPUE was correlated with the recruitment index, computed as fraction of juveniles (immature specimens with CL < 20 mm) on the total of specimens captured. For the female population of *P. longirostris* the size of the smallest mature specimen, the size at first maturity (50% in the population), the mean and median sizes were computed for each year. In particular, the mean size was calculated considering the specimens greater than 20 mm CL in order to avoid the influence of the recruitment. The changes of abundance indices and sizes with time were evaluated by means of regression analysis. For the female population the total mortality rate (Z) was estimated according to the Hoenig (1987) method and its changes with time were tested by means of regression analysis.

Concerning *A. antennatus* and *A. foliacea*, the CPUE in weight (kg/h) and number (N/h) were computed for each seasonal survey carried out between 1996 and 2003 as part of GRUND and MEDITS projects. The size composition of the seasonal surveys carried out during autumn 2002 and spring 2003 were performed.

Results

The density and biomass indices in *P. longirostris* changed greatly during the study period without any significant trend ($p > 0.05$) (Fig. 1). The marked increase of the abundance shown during 1990-91 in both Apulia and Calabrian coasts was due to the great fluctuation of the recruitment, as previously reported in D'Onghia *et al*. (1998). In fact, the CPUE values were significantly correlated to the recruitment index ($p<0.05$) (Fig. 2). Instead, no correlation was detected between density index and Z ($p>0.05$) (Fig. 3). The total mortality rate varied significantly ($p<0.01$) exhibiting an increasing trend during the study period (Fig. 4).

Concerning the sizes, a significant decrease of mean and median with time was shown in the sampled population of *P. longirostris* (CL mean = -0.48year + 32.7, r^2 = 0.89, $p < 0.01$; CL median = -0.61year + 29.3, r^2 = 0.81, $p < 0.01$) whereas the size of the smallest mature specimen and the size at first maturity did not show significant changes ($p > 0.05$). Both mean and median were always smaller than the size at first maturity (Fig. 5).

With regard to the red shrimps, although the studies carried out in the Ionian Sea along the Italian coasts have always showed that *A. antennatus* is largely more abundant than *A. foliacea* (e.g. Tursi *et al.*, 1993; Matarrese *et al.*, 1994; Tursi *et al.*, 1998), in the last surveys the CPUE values were greater in the latter species than in the former (Fig. 6). In the context of great fluctuations observed in the period 1996-2003, the yields of *A. antennatus* and *A. foliacea* showed an evident decreasing and increasing trend, respectively.

From the specimens caught during autumn 2002 (GRUND) and spring 2003 (MEDITS) it was clear, from numbers and sizes, that the abovementioned marked increase of CPUE values in *A. foliacea* was due to a successful recruitment in the study area. In fact, the adult fraction was almost completely lacking from the sampled population. On the contrary, all sizes were represented in the catches of *A. antennatus* (Fig. 7).

Discussion and conclusions

If from one hand the results presented in this paper confirm some effects of fishing on the biological resources, from the other hand they highlight the non-equilibrium conditions in the populations and environment which increase the uncertainty in the application of steady-state stock assessment models.

A typical effect of fishing on *P. longirostris* is the decrease of the adult fraction in the stock that might cause the decrease of the recovery capacity of the population. Although intensively exploited with mean and median sizes in the catches smaller than the size at first maturity, *P. longirostris* is one of the most abundant resources in the Ionian Sea not showing a decline in the abundance but only fluctuations. This could be due to the r-selective characters of its life cycle (Jennings *et al.*, 1998). If from one hand such characters allow a more rapid recovery of the exploited population, from the other hand they make the population more influenced by the stochastic changes in the environment, determining the “boom and bust” nature of the harvest with high changes in the yields (Adams, 1980). No modifications in life-history parameters to the abundance and size variations were revealed in *P. longirostris* during the study period. Even this could be due to the r-selective traits of its life cycle.

Fluctuating yields with an increasing trend in *A. foliacea* and a decreasing pattern in *A. antennatus* were surprisingly shown in contrast with previous observations in the North-western Ionian Sea (e.g. Matarrese *et al.*, 1994; Tursi *et al.*, 1998). However, the stock of *A. foliacea* mostly consisted of small specimens while that of *A. antennatus* showed several size components in agreement with previous studies (Matarrese et al., 1997; D’Onghia *et al.*, 1998a, 1998d).

The effects of fishing on *A. antennatus* are less evident than in *A. foliacea* since the former shows a very wide depth distribution, high renewal capacity and unavailability of the recruitment to the fishing while the latter is mostly distributed on fishing bottoms where both juveniles and adults are vulnerable to the trawling (Orsi Relini and Relini, 1985; Sardà, 1993; Tursi *et al.*, 1996; Sardà and Cartes, 1997; Materrese et al., 1997). In fact, during studies on the red shrimps carried out in exploited and unexploited areas of the North Ionian Sea (Anon., 2001; Politou *et al.*, 2003; Mytilineou *et al.*, in press), the same size structure pattern, with several size classes, was shown in *A. antennatus* in the two areas contrarily to *A. foliacea* whose size composition evidenced the effects of fishing in the Italian side of the Ionian Sea (exploited area) and showed a multimodal trend in the Greek waters (unexploited area).

The significant reduction of the mean and median size in *P. longirostris* during time and the truncate size structure in *A. foliacea* are typical effects of fishing (Jennings and Kaiser, 1998). Instead, the abundance of these two species appears to be strongly correlated with the stochastic variation of the recruitment. In *P. longirostris* the changes in the density do not seem to be affected by the total mortality rate on the stock. On the contrary this rate reflects the size structure in the stock irrespective of the density.

The noteworthy recruitment of *P. longirostris* during 1990-91 was reported by D'Onghia *et al*. (1998c), however the relevant causes were never investigated. Could the recent uncommon abundance of *A. foliacea* on the fishing grounds be due to the "transient"? That is the Eastern Mediterranean hydrological changes which make warmer and more saline the water masses of the North-western Ionian Sea (Klein *et al.*, 1999; Manca *et al.*, 2002). This question follows the hypothesis by Ghidalia and Bourgois (1961) and Bombace (1975) who suggested that *A. foliacea* is preferentially distributed in warmer and high salinity waters than *A. antennatus*. Indeed, this latter species has long been found largely more abundant than the former in the North-western Ionian Sea (cit.op.) which waters are generally colder and less saline than on the eastern side of the basin (Theocharis *et al*., 1993) where *A. foliacea* is greatly more abundant than *A. antennatus* (Anon., 2001; Politou *et al*., 2003; Mytilineou *et al*., in press).

We don't know if such an hypothesis together with other population abundance fluctuations will be explained and correlated to environmental changes through future research. The abovementioned hydrological variations in the waters properties of the Ionian Sea occurred in response to the atmospheric forcing variability (Manca *et al.*, 2002). But what we know about the causes of this variability and of the relevant effects on the marine ecosystem? The recruitment dynamics are often complex and seemingly unpredictable (Fogarty *et al*., 1991). In this respect, worth of mention is the uncommon recruitment of *Aristeus antennatus* verified some years ago in the Ligurian Sea (Orsi Relini and Relini, 1988). In temperate waters living marine resources seem to be strongly affected by non-deterministic physical phenomena (Pauly, 1979).

D'Onghia *et al.* (2003) revealed significant differences in the species distribution and abundance between the fish assemblages studied in two border-marker areas of the North Ionian Sea with different fishing intensity: one off the South-eastern Italian coast, where the red shrimps are usually exploited between 400 and 800 m (Carlucci *et al.*, 2003), the other off north-western Greece, where there is no deep-water trawl fishing (unexploited area) (Anon., 2001). Authors concluded that such differences were most probably due to both different fishing intensity and environmental conditions. The effects of fishing manifest themselves against a background of natural environmental variations that are the major agent of change in the system (Gislason *et al*., 2000). Larkin (1996) reported that the management of marine fisheries according to ecosystem properties is essentially a question of distinguishing the impacts of fishing (top-down effects) from those of fluctuations in the environment (bottom-up effects), understanding the dynamics of species interactions and appreciating the way in which fishing fleets will respond to changes in the abundance of various stocks. However, Larkin (1996) himself reported that although changes in many marine ecosystem have no doubt occurred, efforts to model their holistic dynamics have not yet been successful due to the number of variables involved and the way in which only small errors in their estimation may lead to large effects in the simulated results. According to Stergiou

(2002), in the problems of the assessment of marine biological resources we have to face on the lack of knowledge (subjective uncertainty) together with the variability of the stochastic processes in the populations (objective uncertainty). The distribution and abundance of the organisms are the main topics of the ecology (Krebs, 1972), but few general rules are available to help us predict changes in the population abundance (Lawton, 1999).

Stochastic processes of the populations (recruitment, growth, mortality) are estimated with a considerable uncertainty and therefore used as input parameters in the stock-oriented models. Considering that the fishing truncates the age structure in the populations, the non equilibrium conditions could be enhanced in many species, increasing the dependence of the abundance changes on the stochastic variability of the recruitment and thus increasing uncertainty in the estimates and in the outcome of the models often used as reference points (Stergiou, 2002).

Since different types of uncertainty exist in fisheries management (Caddy and Mahon, 1995; Francis and Shotton, 1996), the benefit of different management measures and actions in a management process could be evaluated in terms of their contribution to reduce uncertainty (Cochrane, 1999). Will the increased complexity implemented in the models (and thus in fisheries management) reduce such uncertainties? Most probably, according to Healey and Hennessey (1998), it will fail because is based on the false belief in the ability to manage fisheries very precisely.

The multi-species nature of Mediterranean fisheries causes further uncertainty due to technical interactions between gears and biological interactions between most of the stocks. On the other hand, the effects of fishing on the habitat and species (target, by-catch and discard), would require the incorporation of ecosystem objectives in the fishery management (Agardy, 2000).

Biological resources in the Mediterranean have been managed until now by means of “input” regulation measures, such licence limitation, time closure, gear restrictions while the results obtained from the application of stock-oriented models, which indicated a marked reduction of fishing effort, have not been implemented in practice. The indisputable progress made in the studies on the Mediterranean living resources (e.g. Relini *et al*., 1999) can further contribute to manage them taking into account three fundamental developments: 1) the monitoring process; 2) the involvement of the major stakeholders in decision-making; 3) the robustness to uncertainties of the management measures.

Since 1985 demersal resources in Italian waters are mostly monitored by scientists in the context of the GRUND project and successively as part of MEDITS. In this respect, governments and stakeholders ask to scientists to provide their best advice, in terms of indicators and reference points that should trigger management actions. The recruitment has represented the main indicator in the institution of the fishing time closure in the Italian waters (within the law 41/1982). Considering the results reported here and the relative discussion, in our opinion the recruitment of the target demersal resources can still constitute the main indicator in order to create “monitoring working groups” (see Lane and Stephenson, 1997 in Cochrane, 1999; Gislason *et al*., 2000) which should be composed by governments managers, scientist, representative of the fleet, representative of the fishermen and fishermen themselves. Such groups should operate to regional level or even at smaller scale (administrative marine district). The roles and responsibilities of the different partners have to be clarified in order to generate consensus in decision-making. In particular, scientists and fishermen have to cooperate in the monitoring process with the aim to obtain real-time information to promote institutional processes for time-area closure in short time. Furthermore, considerable attention should be given to the concept of local management responsibility, strengthening in the local fishermen the sense of ownership of the resources (Larkin, 1996).

The time closure could be adopted for both very high and very low levels of recruitment respect to a reference level considered as b.r.p. in the fishing area and that can be tuned with experience. The time closure could occur in more than one period during year with the consensus of the major stakeholders on the basis of the acquired scientific knowledge supported by the scientific and commercial monitoring. In the Ionian Sea it could be adopted during spring aimed to *P. longirostris*, *A. foliacea* and *A. antennatus* recruitment as well as that concerning gadiform fishes and during autumn for *Mullus barbatus* (Tursi *et al.*, 1998). Two years ago, fishermen in the Taranto marine district (Northern Ionian Sea) decided autonomously to stop trawl fishing, for more than one week, in relation to a massive recruitment of hake and giant red shrimp. Even though the growth of both these two species is negligible in one-two weeks, their distribution on the fishing bottoms can spread out remarkably.

The area closure (even temporary and flexible in space) should be adopted in relation to the presence of nursery areas. A large amount of data are available on these areas along the Italian coasts (e.g. Ardizzone and Corsi eds, 1997; Lembo *et al.*, 2000) and further information can be collected through monitoring surveys (both scientific and commercial). The choice of the no-take zones will depend primarily on the presence of the nurseries. However, other ecological components, such as the presence of particular biocoenoses and spawning areas, can corroborate such a choice with the aim to meet ecosystem objectives in the fishery management. The case of *A. antennatus* in Mediterranean, as briefly recalled in this paper, confirms the importance of refuge areas (no-take zone - MPA for fishery management) where the exploited population can recover (e.g. Gell and Roberts, 2003). Although this shrimp is intensively sought it appears to be underfished or close to the optimal harvesting (Tursi *et al.*, 1996), in contrast with the majority of the demersal resources.

In addition to the above integrated measures, the adoption of a large mesh size in the codend of the trawl net could represent a further contribution in the management of deep-water resources, such as *A. foliacea* and *A. antennatus*, reducing both mortality in juveniles of the species assemblage and discard production with minimal economic losses (Ragonese *et al.*, 1994, 2001; Bianchini *et al.*, 1998; D'Onghia *et al.*, 1998b, 2003; Imperatrice *et al.*, 2003; Carlucci *et al.*, in press). However, also this management tool requires the involvement of fishermen and the representative of the fleet adopting a differential regulation of the mesh size for the coastal trawling (actual mesh size in the European Mediterranean countries) and for the deep-water trawling.

Both time-area closure and large mesh size adoptions constitute management measures robust to uncertainties and suitable for multi-species management (Cochrane, 1999). The performance of these integrated measures should be monitored and tested with the aim of identifying a management system which satisfy ecological, socio-economic and political contexts.

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A REFERENCE POINT MODEL FOR MULTI-SPECIES FISHERIES

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Abstract

A mathematical model for reference points in a multi-species fishery is presented. The model is based upon weighted yield per recruit functions. The model defines the two usual reference points, F_{max} and $F_{0.1}$. Reproductive success is incorporated via the reproductive value function as an ecological weight. Commercial value is also incorporated as an economic weight. The model is applied to the red shrimp deep-water bottom trawl fishery in the Ionian Sea (Central-Eastern Mediterranean Sea).

Key words: deep-water trawl fishing, multi-species fisheries, reproductive value, yield per recruit.

1. Introduction

Biological reference points have assumed a place of importance in the theory of exploited populations. One of the reasons their definitions and properties continue to be active areas of research is that they are meant to substitute for the large amount of fundamental information about population dynamics that remains unknown at this time.

The issues surrounding reference points and a generalized definition of reference points are found in the FAO publication, *Reference Points for Fisheries Management* (Caddy and Mahon, 1995). The definition given is: “a conventional value, derived from technical analysis, which represents a state of the fishery or population, and whose characteristics are believed to be useful for the management of the unit stock”.

On the one hand, the definition is vague, meaning that many different types of reference point models can be defined to satisfy it and, on the other hand, it is constraining, limiting the types of applications that can be envisioned. We propose a model adapted to respond to several limitations of existing reference point models. The unit stock is one of the limitations of the above definition in the FAO report (Caddy and Mahon, 1995). The proposed model utilizes the technical analysis of the Beverton and Holt model and traditional, target reference points based on the rates of fishing mortality, $F_{0.1}$ and F_{max}. Although the Beverton and Holt model assumes a unit stock, an ecosystem level perspective is introduced. The ecosystem properties are represented by a multi-species fishery. This is one of the recommendation found in the FAO report (Caddy and Mahon, 1995) where it is noted, “that the incorporation of (multi-species) considerations into management advice has, however, been difficult to achieve.”

1.1 A Proposed Reference Point Model

The proposed model explicitly recognizes that all species in a catch will not necessarily have the same economic value. While some species will certainly have market value other species may be both abundant and without market value.

The proposed model also responds to concerns expressed about reference points based upon yield models (Gulland and Borema, 1973) that assume steady state conditions. However, harvests at F-values used early in the harvest history under a steady state situation may cause, or exacerbate, recruitment overfishing in a developed fishery (Sissenwine and Shepherd, 1987), thereby inducing reduced harvest levels, causing a downward spiral. Another class of reference points that specifically target levels of fishing effort unlikely to induce recruitment overfishing have been defined. If the spawning stock biomass is SSB and recruitment is R, R/SSB measures the observed level of recruitment per unit of SSB (Sissenwine and Shepherd, 1987). These reference points, based on the median of F-values that satisfy the above, and others, are in Gabriel et al. (1989) and Clark (1991).

The proposed model incorporates some of the above reproductive considerations via the use of the reproductive value of each species. The reproductive value for the ith species is the sum of the contributions at each age, x, to the next generation. This contribution, a function of x, is estimated with demographic parameters for fecundity f_x, survival l_x, and the rate of change of population size ?, considered constant for all ages (Pielou, 1969). Since reproductive value RV_x is based on demographic parameters and not reproductive effort, species with different reproductive modes such as fish with millions of eggs, sharks with a few embryos, and shrimp with thousands of eggs, can all be represented by the same equation. Therefore, this function automatically incorporates life history characteristics and allows comparisons across species. This equation, repeated below, is:

$$RV_x = \sum_i \lambda^{-(i-x)} f_i \frac{l_i}{l_x}$$

The synthesis of RV_x functions per species constitute the ecological weights.

1.2 Application of the model

The proposed model is demonstrated by applying it to the deep water trawl fishery in the Mediterranean Sea. The fishery targets the red shrimps *Aristeus antennatus* (Risso, 1816) and *Aristaeomorpha foliacea* (Risso, 1827), the shrimp species with the highest economic value, and secondarily, other demersal resources found on the continental slope down to 800 m (Bianchini and Ragonese, 1994). Since a trawl fishery affects the whole demersal community, a precautionary approach would account for the differing life history patterns of all the affected species, those with and without economic value. This would be consistent with international agreements such as the *Convention on Biodiversity*, the *FAO Code of Conduct for Responsible Fisheries*, and the *Convention of Barcelona*, all of which advocate management regimes characterized by ecosystem approaches to sustainable exploitation. The proposed quantitative model estimates two reference points, the instantaneous rates of fishing mortality $F_{max\ MS}$ and $F_{0.1\ MS,}$ each weighted by ecological and economic terms for the suite of species the trawl encounters, instead of for a single species (the subscript “MS” represents multi-species).

Of the targeted red shrimps, *A. antennatus* is more abundant on the western side of the Mediterranean and *A. foliacea* is more abundant in the central-eastern but the abundance of both species fluctuates greatly on the fishing grounds and in the catches (Cau *et al*. 2002). Juveniles and adults are captured with economic value increasing with size. Although red shrimps are targeted, by-catch species also occur in the catches. For example, in the Ionian Sea (Central-Eastern Mediterranean Sea) red shrimps may constitute up to 58.60% in weight and 66.15% of the economic value of the total catch (Carlucci *et al*., 2003). By-catch species, such as the crustaceans *Plesionika martia* and *Nephrops novegicus,* and the fishes *Merluccius merluccius, Micromesistius poutassou, Phycis blennoides, Helicolenus dactyloperus* and *Lepidorhombus boscii,* contribute the remainder of the economic value (D’Onghia *et al*., 2003). In addition, other by-catch species such as the selachians, *Galeus melastomus* and *Etmopterus spinax,* and the teleosts, *Hoplostethus mediterraneus*, *Caelorhynchus caelorhynchus*, *Nezumia schlerorhynchus* and *Hymenocephalus italicus* are discarded because of the absence of a market (D'Onghia *et al*., 1997; 2003). Despite these differences, the life-history traits of all of the species that occur in the trawls can be quantified by demographic parameters such as longevity, age at first reproduction, length of the spawning season, fecundity, etc.

2. Materials and methods

2.1 Description of the Model

The model and the related biological reference points presented in this paper begin with Beverton and Holt's yield per recruit model (1957):

$$Y/R = FW_{\infty}e^{-M(t_c - t_?)}\sum_{n=0}^{3}\frac{O_n e^{-nk(t_c - t_0)}}{F + M + nk}\left(1 - e^{-(F+M+nk)(t_? - t_c)}\right)$$

$$O_0 = 1, O_1 = -3, O_2 = 3, O_3 = -1$$

The underlying assumptions for this model are: 1. growth is isometric ($W=aL^3$) and follows a von Bertalanffy function (with parameters L_8, k and t_0); 2. the instantaneous rates of fishing and natural mortality (F and M) are constant; 3. as are the ages of entry to the fishery (t_c), the age of biological recruitment ($t_?$), and the maximum age of exploitation ($t_?$); 4. a steady state in time. These hypotheses are assumed reasonably satisfied in the multi-species model for each species, and each could be considered a unit stock.

The two reference points are defined from the yield per recruit function (Y/R) and visualized when Y/R is plotted versus F: F_{max} is the F-value corresponding to the maximum of the yield function and $F_{0.1}$ is the F-value corresponding to the slope of the yield function at 10% of the slope it has at the origin (Gulland and Borema, 1973).

The multi-species model is built as a combination of the yield per recruit functions for the species retained in the trawl. That is,

$$Y/R_{MS} = \sum_{i=1}^{S} w_i \cdot Y/R_i$$

where, Y/R_{MS} is the weighted mean of the yield per recruit functions for the S species that occur in the trawl. The weights w_i are defined for each species i as the arithmetic mean of an ecological weight (w_E) and an economic weight ($w_\$$). That is,

$$w_i = \frac{w_{E,i} + w_{\$,i}}{2}, \text{ with } \sum_i w_{E,i} = \sum_i w_{\$,i} = 1$$

The ecological weight of species i is the reproductive values of the species weighted by its relative abundance in the catch, viz.,

$$w_{E,i} = \frac{f_i \cdot RV_i}{\sum_{i=1}^{S} f_i \cdot RV_i}$$

where the frequency of occurrence of the i-th species in the catch is defined as the ratio of the number of samples in which the species is caught, n_i, and the total number of samples, N_T:

$$f_i = \frac{n_i}{N_T}$$

As noted above (1), a reproductive value is estimated for each species from its demographic parameters. A net reproductive value is estimated as the square root of the sum of the squares of the individual vectors of reproductive values, RV_x, each defined as above in (1) by:

$$RV_x = \sum_i ?^{-(i-x)} f_i \frac{l_i}{l_x}$$

The economic weight of each species is calculated as the fraction of its commercial value over the sum of the commercial values of all the species.

2.2 Application of the model

We apply the multi-species yield per recruit model to a suite of five species that characterize the deep-sea red shrimp fishery and captures in the Northern Ionian Sea. The life-history parameters for the species considered in this paper are summarized in Table 1.

These five species are: two commercial target species, the blue and red shrimp *Aristeus antennatus* (Risso, 1816) and the giant red shrimp *Aristaeomorpha foliacea* (Risso, 1827); two commercial by-catch species, the golden shrimp *Plesionika martia* (A. Milne Edwards, 1883) and the greater forkbeard *Phycis blennoides* (Brünnich, 1768); a discard species, the blackmouth catshark *Galeus melastomus* (Rafinesque, 1810). These species were selected because they occur in the trawl and because reasonable estimates of their demographic parameters are possible. However, even these estimates are sometimes approximations. More accurate data will need to be collected to obtain more representative curves and reference points. The estimates in Table 1 are drawn mainly from the studies carried out in the Ionian Sea.

According to Orsi Relini and Relini (1998) and Capezzuto *et al*. (in press) a longevity up to 9-10 years can be assumed for *A. antennatus* while the life-span of *A. foliacea* could be around 7-8 years (D'Onghia *et al*., 1998). However, these numbers are presently uncertain. *A. antennatus* does seem to live longer than *A. foliacea*, but its age at first maturity is lower (Tursi *et al*., 1996). The fecundity of large female *A. antennatus* is up to 4 times that of *A. foliacea* (Orsi Relini and Semeira, 1983) but its total mortality rate is lower. The higher mortality rate of *A. foliacea* is due primarily to its greater availability to the fishery.

The golden shrimp *P. martia* is a short lived species, with an estimated longevity of 4 years (Maiorano *et al*., 2002). The age at first maturity (50% of the ovigerous females) is in the second year, at about 15.5 mm CL. The fecundity parameter is the size of the brood of eggs in stage 3 (ready to spawn) which varied from 650 to 6627 eggs. Since this shrimp spawns a smaller number of larger eggs than the red shrimps, a higher survival rate of offspring is hypothesized.

The black-mouth shark, *G. melastomus*, is a long-lived species showing a multi-aged population structure and a vertical distribution extending to 1500 m in the Ionian Sea (Tursi *et al.*, 1993; Sion *et al.*, in press). Age of first reproduction is 4 with up to 8 egg capsules per large female (Tursi *et al.*, 1993). Among the five species considered, *G. melastomus* offspring have the highest probability survival. The bony fish greater forkbeard, *P. blennoides*, is a long-lived iteroparous species with late maturity and high fecundity. A gonad from a mature female (70.3 cm TL) in the Ionian Sea weighed 260.1 g. The telolecithal eggs had diameters from 200 to 590 µm (Matarrese *et al*., 1998). This fish shows synchronous winter spawning (Matarrese *et al*., 1998; Relini *et al*., 1999).

Big specimens are scarce in the trawl catches since they generally occur at greater depths than the trawl generally fishes.

3 Results

Fig. 1 shows the probabilities of survival of individuals of age x to the age x+1 (l_x) for each of the species in the suite. Fig. 2 shows the fecundity per age x (m_x) for each species in the suite. Fecundity is defined as the average number of female offspring of a female of age x.

Fig. 3 are curves for RV_x, the reproductive value, for an individual of age x, for each species in the suite. Reproductive value is used to estimate an ecological weight, as the square root of the sum of the squares of RV_x; the values ranged from 10.03 for the golden shrimp, *Plesionika martia*, to 99.79 for the greater forkbeard *Phycis blennoides*. Fig. 4 shows the multi-species weighted yield per recruit curve along with the single species curves vs F. The values of F_{max} and $F_{0.1}$ of multi-species and of the single-species functions are estimated and are shown in Tab. 2. F_{max} ranged from 0.19 y^{-1}, for the two fish species, to a maximum of 1.17 y^{-1}, for the golden shrimp *P. martia*. $F_{0.1}$ ranged from 0.13 to 0.67 y^{-1} with the same pattern as seen for the first mortality rate above. The shark species *G. melastomus* showed the highest value of the maximum of the yield per recruit function (53.11), while the shrimp *P. martia* displayed the lowest (1.01). For the multi-species yield per recruit function, F_{max} was 0.21 y^{-1} and $F_{0.1}$ was estimated to be 0.14 y^{-1}. The maximum yield per recruit for the multi-species function was equal to 22.85.

4 Discussion

The values of F_{max} estimated for the three crustacean species were higher than the value from the multi-species model, while the single-species F_{max}-values of the two fish species were very similar to $F_{max\ MS}$. The same pattern arises comparing the single-species and the multi-species $F_{0.1}$-values obtained, with $F_{0.1}$-values higher for the three crustaceans and almost identical for the two fish if compared to $F_{0.1\ MS}$. Therefore, in this application of the proposed model, adopting $F_{max\ MS}$ or $F_{0.1\ MS}$ as the reference point would be a conservative management measure for the three crustaceans present in the fishery and be approximately equivalent to the usual single species yield per recruit F-values for the two fish species.

Furthermore, since the F-values for *A. antennatus* and *A. foliacea* are considerably higher than those of the two fish, using the mono-specific giant shrimp reference points would over-exploit the two fish species and the third shrimp species. If the overall abundance of these species were to drop very low, the diversity of the demersal community would be decreased.

It is expected that the value of $F_{0.1}$ will be less than F_{max} based on theoretical considerations. It is interesting to examine the amount of difference between these reference points. The shape of the yield per recruit curve will determine the difference between the two reference points. In the application presented here the difference is 0.07, probably not statistically significant different from the corresponding values for the by-catch species.

The proposed model offers an opportunity to choose a reference point based on flexible ecological and economic weights that can be adjusted to represent the circumstances of a particular fishery, all while remaining within a single framework. The version that was presented here assigned equal weights to economic and ecological factors. The weighting system used here led to clear differences between all five species in the suite and the weighted average multi-species reference point.

Aside from the particular advantages of the proposed reference point model the disadvantage is that it is highly data intensive. Not only are the data needs high, many of the required demographic parameters are not traditionally collected by biologists, especially for deep-water ecosystems such as was chosen for the application. Aside from the necessity of collecting new biological data for the model, an additional consequence will be improved estimation of some of the usual stock assessment parameters, such as the instantaneous rate of natural mortality. A sensitivity analysis is the next step in the exploration of the model to determine the effect of changes in the values of weights.

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Tab. 1

	A. antennatus	*A. foliacea*	*P. blennoides*	*G. melastomus*	*P. martia*
W_8 (g)	160,77	94,52	1876,12	681,20	17,32
k (y^{-1})	0,22	0,45	0,13	0,22	0,44
t_0 (y)	-0,23	-0,18	-0,77	-0,05	-0,05
M (y^{-1})	0,26	0,48	0,28	0,20	0,69
t_c (y)	0,97	0,47	0,30	0,80	1,07
$t_?$ (y)	0,26	0,09	0,04	0,70	0,45
$t_?$ (y)	9,20	5,77	25,00	15,00	4,30
f	35,00	20,00	51,81	31,61	20,00
R.V.	41,84	17,00	99,79	30,16	10,03
w_E	0,18	0,04	0,64	0,12	0,02
$w_\$$	0,48	0,30	0,16	0,00	0,06

Tab. 2

	MULTI-SPECIES	*A. antennatus*	*A. foliacea*	*P. blennoides*	*G. melastomus*	*P. martia*
$F_{max}(y^{-1})$	0.21	0.30	0.52	0.19	0.19	1.17
$F_{0.1}(y^{-1})$	0,14	0.20	0.35	0.13	0.13	0.67
Y/R_{max}	22.85	8.69	6.31	40.57	53.11	1.01

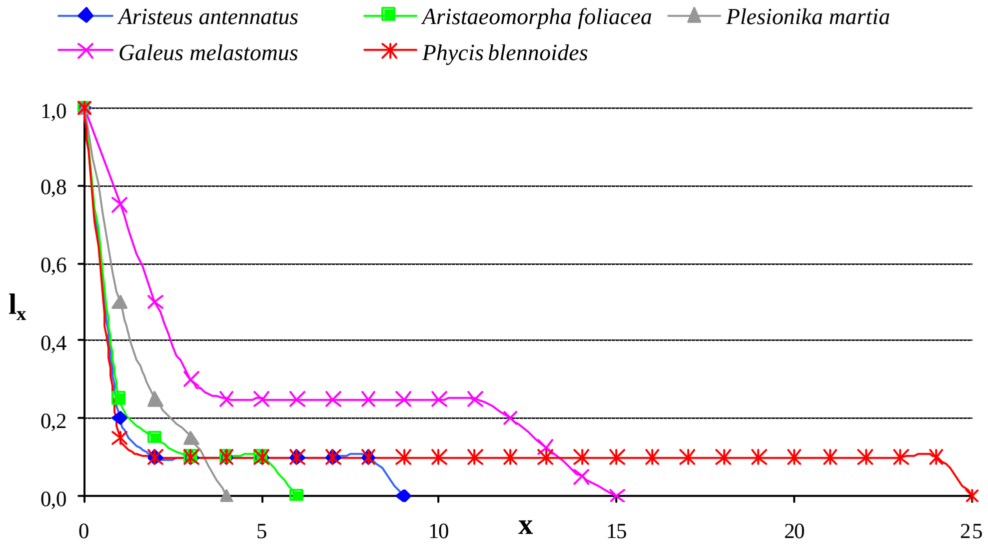

Fig. 1

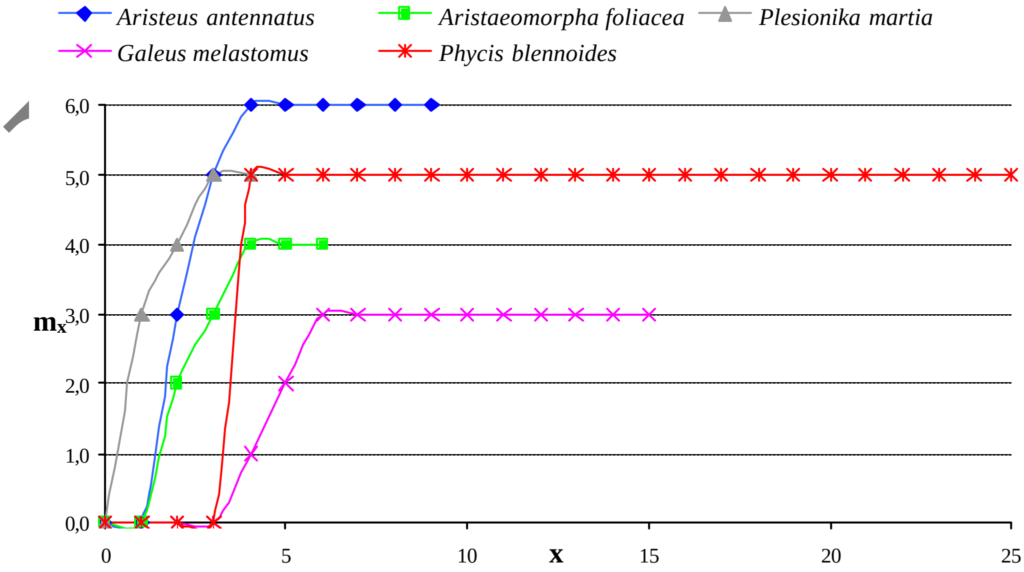

Fig. 2

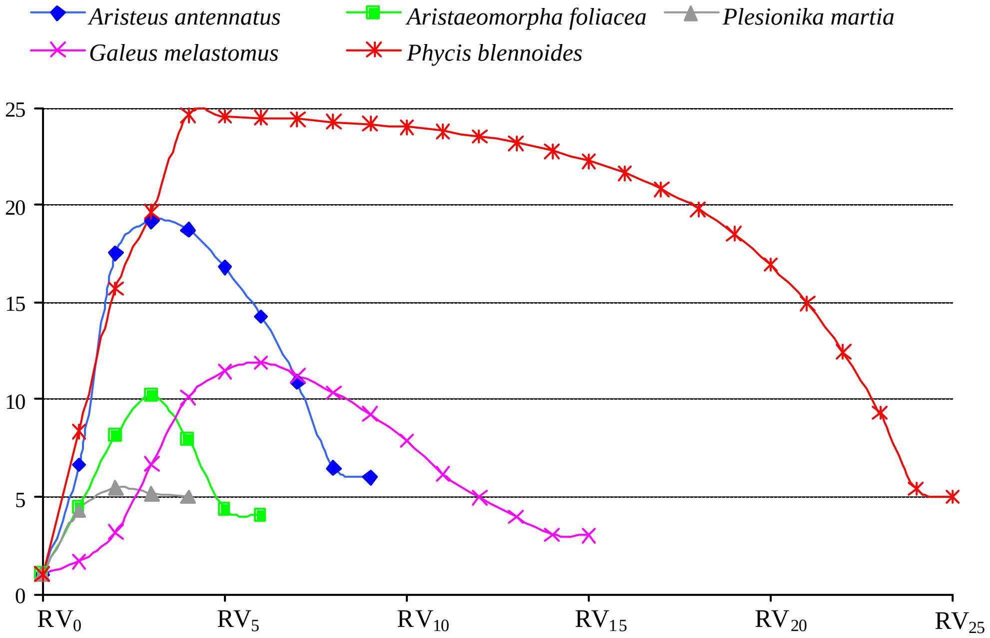
Aristeus antennatus
Aristaeomorpha foliacea
Plesionika martia
Galeus melastomus
Phycis blennoides
25
20
15
10
5
0
RV_0
RV_5
RV_{10}
RV_{15}
RV_{20}
RV_{25}

Fig. 3

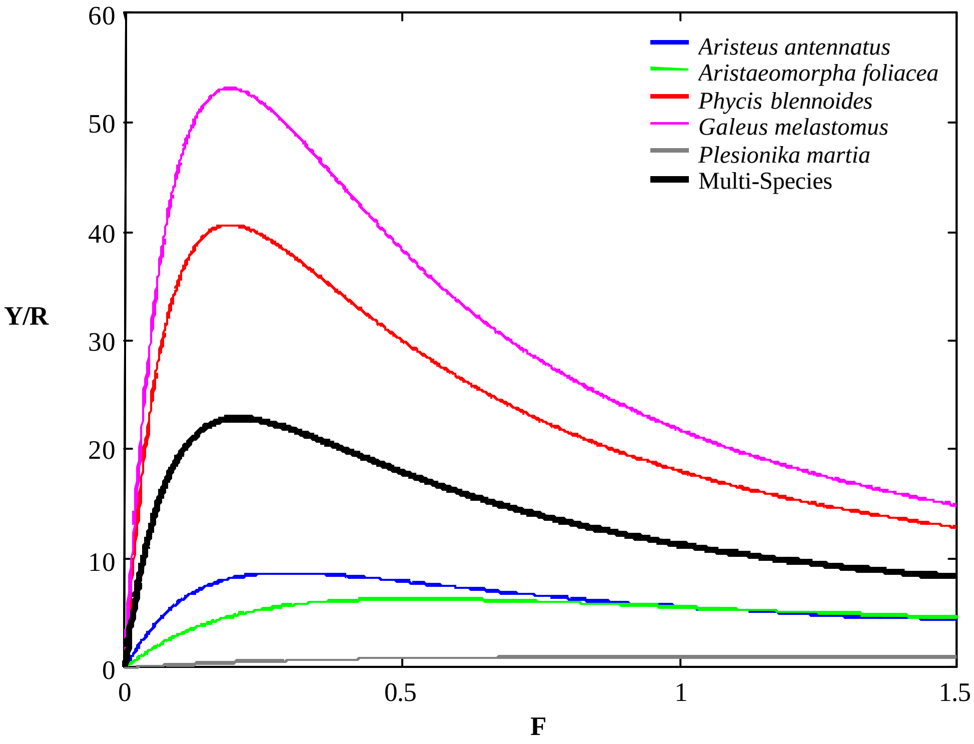
Aristeus antennatus
Aristaeomorpha foliacea
Phycis blennoides
Galeus melastomus
Plesionika martia
Multi-Species
Y/R
60
50
40
30
20
10
0
0
0.5
1
1.5
F

Fig. 4

Tables legend

Tab. 1 – Life history parameters and other input parameters of the multi-species yield per recruit model.

Tab. 2 – Estimated values of F_{max}, $F_{0.1}$ and Y/R_{max} for the multi-species and for the single-species yield per recruit functions.

Figures legend

Fig. 1 - Values of probability of survival (l_x) per age of the five species considered.

Fig. 2 - Values of the fecundity (m_x) per age of the five species considered.

Fig. 3 - Reproductive values (RV_x) of the five species considered.

Fig. 4 – Single-species and multi-species yield per recruit curves obtained.

IDENTIFICATION OF REFERENCE POINTS FOR THE NORTHERN AND CENTRAL ADRIATIC DEMERSAL STOCKS

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Abstract

The potential use of simple indicators of state of demersal stock in the Adriatic GSA 17 is verified using processed data from Medits trawl surveys carried out in the Northern and Central Adriatic Sea from 1994 to 2003.

Density indices calculated in area of different exploitation and demographic structure of the population are analysed for *Merluccius merluccius*, *Mullus barbatus*, *Nephrops norvegicus*, and *Loligo vulgaris* to verify different problems.

The potential suitability and the meaning of their experimental values is discussed for each biological indicator to individuate the potential warning and alarm limit values.

The results show the interest in the use of some of the indicators considered as Reference Points useful in demersal resources management.

Key-words: Adriatic sea, biological indicators, demersal stock, Reference Points.

1 Introduction

Difficulties in the management of the fish stock and fishery are also due to the low confidence of fishermen and other non technical operators in language and advice of researcher. The consequence is the difficulty and sometimes the opposition from fishermen to accept and apply management measures and rules that they don't understand and don't share.

This work analyses the possibility to identify some biological indicators of stock state, comprehensible by fishermen and useful in demersal resources management.

In the Northern and Central Adriatic Sea (GSA 17) we have ten years of data available from Medits trawl surveys that could be useful to this aim.

The potential suitability and the meaning of their experimental values, obtained throughout ten years trawl-surveys, is discussed for each indicator to individuate the potential warning and alarm limit values. Four of the most economically important species for trawl fishing activity in this area and with different biology have been analysed to verify different problems using these indicators.

A first aspect to consider concerns the Adriatic Sea and the extension of the area to examine. Do different areas show the same trend in abundance? How changes abundance if region (Italy, Croatia, Slovenia) with different resources exploitation are considered? Is abundance more influenced by different environmental features?

In Adriatic Sea fishery is mainly concentrated on juveniles (Piccinetti e Piccinetti Manfrin, 1994) and trend in abundance reflect fluctuations in recruitment (Arneri, 1996). A second point to take into account is size composition of the population and how change through the years.

The aim of this study is not to identify values for an optimal specie exploitation, but identify warning values to avoid resources collapse.

2 Methodology

Collected data from Medits trawl-surveys carried out in the Italian territorial waters and international waters from 1994 to 2003 have been used. From the 1996, when Croatia and Slovenia joined in the Medits programme, sampling was carried out also in Croatian and Slovenian territorial waters, covering all the entire Northern and Central basin.

Every year sampling was carried out in June and July using the same protocol for sampling and methodology of data analysis (Bertrand et al., 1997). A trawl net with mesh cod-end size of 20 mm was always used.

On an average, 130 hauls were sampled every year on the basis of a stratified scheme with random selection of stations. A total number of 1308 hauls was sampled.

Data processing, from Medits surveys, assumes that total number, weight and size distribution of catches are proportional to the real density and size composition of the population in sea.

A first easy indicator is the total density or number of fishes caught in a certain area. The analysis of this value between different years shows how fishes number changes in a certain area during time.

Total density index (total number of specimens per km^2), was calculated for *Merluccius merluccius* (Linnaeus, 1758), *Mullus barbatus* (Linnaeus, 1758), *Nephrops norvegicus* (Linnaeus, 1758) and *Loligo vulgaris* (Lamarck, 1798) examining the following areas with different extension:

- GSA 17: that extends for more than 92 000 km^2 and covers the whole extension of the Northern and Central Adriatic basin including also Croatian and Slovenian territorial waters;
- North and Middle Adriatic: that extends for about 60 350 km^2 including only italian and international waters;
- North Adriatic: that extends for about 25 500 km^2 including italian and international waters to the north of Ancona-Zadar line;
- Middle Adriatic: that extends for about 34 850 km^2 including italian and international waters between Ancona-Zadar line and Gargano-Kotor line;
- Middle Adriatic (Stratum 10-100m): that extends for about 15 500 km^2 including only waters of the Middle Adriatic with depth between 10 and 100 meters.

In 1999 total density index was not calculated for the entire GSA 17 because the survey was not carried out in Croatia and Slovenia due to war.

Starting from the results obtained on different areas, the best area of investigation to define potential Reference points was chosen.

Considering this area, the following indicators, chosen for their easy comprehensibility, were analysed for each specie:

- Total density index in terms of total number of specimens per km^2;
- Recruitment in terms of number of specimens under a limit size per km^2;
- Spawners in terms of number of specimens in reproductive age per km^2;
- Ratio between recruitment of one year and spawners of previous year;
- Mean, mode and median values calculated for lengths distribution of the entire population;
- Mean mode and median values calculated for adults lengths distribution;

Recruits are defined as individuals younger than one year old with a limit size obtained considering birth period. The limit size of spawners is the size at first maturity (50%)

calculated for males and females population taken together. These limit length values are fixed equal for all years although there are some differences between years.

Density and biomass indices and their CV are calculated using uniform methodology established in international session by all research groups which participate in Medits program.

The investigation could be extended to all other principal species.

3 Results

3.1 Study of area

This part of the research aim to evaluate difference in trend of abundance between different areas to define the better area for Reference Points.

3.1.1 *Merluccius merluccius*

European hake (*Merluccius merluccius*) is distributed throughout the Adriatic with the exception of limited areas to the north of the Po delta (Frattini and Paolini, 1995). Depth distribution is from only several meters in the coastal area to 800 m in the South Adriatic Pit even if it is most abundant at depths between 100 and 200 m, where the catches are mainly composed of juveniles (Ungaro et al., 2003).

Hake density indices calculated for five different areas are reported in Figure 1.

In the area of the North and Middle Adriatic density indices range between 527 in 2003 and 1229 specimens per km^2 in 1995. CV values are always under 18%.

Density values in the GSA 17 are generally higher and range between 663 and 992 hakes per km^2 respectively in 2000 and 1996. CV values are always lower than 11%.

Highest abundance are recorded every year in the area of Middle Adriatic where is recorded the highest values in 1995 (1800 specimens per km^2). Lowest values are always calculated in the North Adriatic, where a reduction in abundance trend is pointed out with densities decrease from 1994 to 2003 (respectively from 624 to 87 specimens per km^2). CV are always lower than 21%.

3.1.2 *Mullus barbatus*

Red mullet (*Mullus barbatus*) prefers the more shallow waters of the Northern and Central Adriatic with depths above 100 metres, while only few specimens may be caught in deeper waters (Jukic e Piccinetti, 1981).

Mullus barbatus mean densities calculated in different areas are reported in Figure 2. Values are calculated for GSA 17, North and Middle Adriatic area, North Adriatic area and Middle Adriatic (Stratum 10-100 m).

In the North and Middle Adriatic indices range between 203 and 2961 specimens per km^2 showing wide variations. CV values are also very high (20-42%). In all studied area abundance values are mainly constant with the exception of 1999 when the highest values are recorded with density values 20 times higher than values recorded in other years. The anomalous values, observed in 1999, in Adriatic sea is influenced by two factors: first, the war events in the Balkan area caused an extended fishing stop period and consequentially there was a reduction of commercial fishing activity. Second, a delay of some months in the trawl survey sampling, due to war, cause also the catch of recruits that usually there are not present when survey is carried out in June.

Excluding 1999 (2961 and 4345 specimens per km^2 respectively in the North and Middle Adriatic area and in the North Adriatic), in the North Adriatic density values change from 135 to 557 specimens per km^2 (CV always lower than 46%); in the area of the North and Middle Adriatic density range between 203 and 709 specimens per km^2

(CV always lower than 42%). GSA 17 densities are higher and change between 365 in 1998 and 857 specimens per km^2 in 2001 with CV always lower than 30%.

3.1.3 *Nephrops norvegicus*

Norway lobster (*Nephrops norvegicus*) lives in depths from 30 metres in the Northern Adriatic to 400 meters in the southern part of the Sea but the most populated settlement is in the Pomo Pit (Vrgoc et al., 2004).

Figure 3 shows mean density values for Norway lobster calculated for GSA 17 area, North and Middle Adriatic area, Middle Adriatic area and Middle Adriatic (stratum 10-100m). All examined areas show a parallel trend of density values with wide variations between years. Middle Adriatic area shows highest densities with values ranging between 31 specimens in 2000 and 396 specimens per km^2 in 1998 (CV between 21 and 69%). Density index in the North and Middle Adriatic ranges between 27 to 230 specimens per km^2. CV values are always under 38% except in 2001 when variability is greater. GSA 17 shows the lowest value in 2002 (58 specimens per km^2) and the highest value in 1996 (282 lobsters per km^2); CV range between 20 and 80%).

The large difference recorded between higher density values obtained in the Middle Adriatic area and lower values obtained in the Middle Adriatic (stratum 10-100m) confirm the importance of area deeper than 100 metres for Norway lobster distribution.

3.1.4 *Loligo vulgaris*

European squid (*Loligo vulgaris*) is distributed throughout the Adriatic Sea up to depths of 400 meters and it migrates into shallower regions during the spawning period. Nevertheless, it is most frequent up to depths of 100 meters (Soro e Piccinetti Manfrin, 1989). Figure 4 shows European squid density values calculated for every five area mentioned above.

This population shows a particularly trend, with 5 years lacking in abundance from 1994 to 1998 (10 specimens per km^2 on an average) and 5 following years of large presence in every examined area.

1999 shows highest values for the North and Middle Adriatic area (789 squids per km^2) and for the North Adriatic area (1589 squids per km^2). Highest value in Middle Adriatic area and Middle Adriatic (stratum 10-100m) are recorded in 2002 (respectively 583 e1284 squids per km^2).

3.2 Study of population composition

North and Middle Adriatic area is examined to calculate indices for different fraction of population. For each specie, figures report trends of density for different fraction of population and also total density for the whole population.

3.2.1 Merluccius merluccius

Data are reported in Figure 5a. For this specie three classes have been considered: recruitment, spawners and intermediate class. Specimens under 120 mm of total length, a size that young hakes reach in variable period but always under one year old, are considered recruits (Campillo, 1992). Specimens between 120 and 270 mm of total length are considered the intermediate class. This is a large range that includes hakes just recruited but under first reproduction length and object of fishery. Male hake mature at length between 20 and 28 cm and female hake at length between 23 and 33 cm (Županovic and Jardas, 1986); a mean size of 270 mm has been considered the limit length for spawners both males and females.

Recruits number changes from 98 in 1999 to 417 specimens per km^2 in 2001 shows fluctuations over 100% through years and CV values are under 25%. This indicator seems to reflect recruits magnitude and shows a large variability of recruitment between years.

Density index for hake between 12 and 27 cm of total length changes from 208 to 804 specimens per km^2 and the lowest value is recorded in 2003. This fraction is the largest of the population and most of the trawling captures are of fishes below 20 cm of total length, belonging to this range (Ungaro et al., 2003).

Figure 5b points out trend for spawning stock density that ranges between 18 to 54 specimens per km^2 with CV under 20%. Spawners density seems to be an useful indicator for management. The lowest number of spawners has been recorded in 2000, there is a constant increase of spawners during following years.

Warning limit could be fixed at 20 spawners per km^2.

3.2.2 *Mullus barbatus*

Figure 6a shows trend for recruitment, intermediate size and spawners indices of *Mullus barbatus*.

Specimens of Red mullet under 10 cm of total length are considered recruits (Ardizzone, 1998). Red mullet born from spawning of May/June, usually reach 12 cm of total length in November of the same year; so specimens under 10 cm are less than 6 months old. Medits sampling usually is in June-July, so recruits are usually not caught or are caught in a little number.

On the other hand, Red mullet reproductive period could change from year to year and just a shift of one month in reproductive period causes high variability in recruitment catches. So recruits density value from Medits data doesn’t reflect the real recruitment and a more reliable index has to be individuate to evaluate this fraction of population.

Recruitment values range between 1 to 1323 specimens per km^2 in 1999 when sampling was carried out with a delay of some months. Probably recruits density obtained in this year is a more reliable index of Red mullet recruitment.

Red mullets belonging to intermediate class are not in reproductive age and sometimes are the result of an autumnal reproduction in the previous year. Index values for this fraction change from 57 to 1100 specimens per km^2 and the highest value is recorded in 1999 when a large number of specimens born during the year overall 10 cm of total length.

Spawners, in terms of specimens over 13 cm of total length, show less variability: values range between 101 to 485 specimens per km^2 with the highest value in 1999. In the other years values almost range from 140 to 165 specimens per km^2 (Figure 6b). In the case of Red mullet warning limit value for spawners could be less than 100 specimens per km^2 because also with this spawners density, following recruitment remain in mean values.

The use of data about age would be better than a fixed length to evaluate *Mullus barbatus* recruitment. In this way recruits born in the year could be divided from specimens born in the previous years without consider size that is influenced by different growth rates during the first year of age.

3.2.3 *Nephrops norvegicus*

Figure 7 shows trend of density for three different size classes of Norway lobster.

Density index of recruitment, considered as specimens under 20 mm of carapace length (Marano et al., 1998), changes from 0.15 to 17 specimens per km^2 and shows marked fluctuations without a clear trend between years. Density index for Norway lobster of 20-25 mm of carapace length, a size that includes recruit lobsters under first maturity length, shows high values ranging from 6 to 67 specimens per km^2.

Spawners are considered as Norway lobster over 25 mm of carapace length, a size which 50% of females begin to mature (Marano et al., 1998). Spawners density values change from 20 to 145 Norway lobsters per km^2. There is a parallel trend of density values of three group mentioned above instead of the expected delay of, at least, one year between density fluctuations of recruitment, intermediate class and spawners. In addition recruitment density value are always lower than values recorded for adults fractions. This fact is due to the behaviour of this specie that spends most of its life buried in borrows in the sea sediment. This behaviour is more obvious in ovigerous females and younger specimens (Froglia, 1972). So density values would be influenced by factors correlated to specie catchability more than to the real abundance of each group.

Based on data, although limitations described above, the warning limit value could be fixed at 20 spawners per km^2.

3.2.4 *Loligo vulgaris*

Figure 8 reports trend of density for European squid.

Loligo vulgaris have a short life cycle with an high growth rate, reproduction in the first life year and death after reproduction so just a little number of *Loligo vulgaris* reaches 2 years. In the case of European squid only 2 classes have been considered: recruits, with a mantle length under 90 mm, a size that juveniles reach few months after hatching, and adults which overstep this size.

There is high variability for the recruitment with values change from 1 to over 700 specimens per km^2. The highest value was recorded in 1999 that represents the boundary line between the first five lacking abundance years and successive 5 more abundance years.

For adults, values change from at least 2 to 84 specimens per km^2.

Although uncertainties related to fast growth, this specie shows high fluctuations between years but also the capacity to recover and produce high recruitment starting from adults low values. Warning limit could be fixed at 2 adults per km^2 .

3.3 Spawners-recruit ratio

Spawners have been divided from recruitment on the base of biology specie knowledge and length. The ratio between recruit of one year and spawners of previous year is reported in Table 1 to evaluate the potential use of this index.

In the case of *Merluccius merluccius* for each spawner in 1994 there have been 7 recruits in 1995 and this ratio keep constant during following years until recruitment in 2000. During the following three years this ratio changes strongly with 22 recruits for a spawner. On the whole the ratio changes from 4 to 22; it is not a constant ratio and shows the importance of natural mortality causes that act between reproduction and recruitment.

For *Mullus barbatus* values are lower than 1 in each year except for ratio between recruits in 1999 and spawners in 1998 that shows a very high value (8.31). These anomalous values confirm that Red mullet recruit index is not correct and must be estimated in a different way. To obtained a correct recruitment index, the number of recruits estimates during autumnal surveys could be used instead the number estimates in spring and summer.

Norway Lobster values are also very low, always less than 1, and range between 0.02 to 0.71. In relation to the particular behaviour of this specie to live in burrows, there is suspect that values represent catchability rather than specie abundance. So the total catch could not be a good indicator of the real abundance of this specie; this aspect must be investigated because also fishery feels the effects of the same factors.

Squid shows a very variable recruitment/spawners ratio with values range between 0 to 263. The short biological cycle and the strong recruitment variability influence this specie: probably a more accurate definition of recruitment could improve this information.

3.4 Lengths distribution

Length distribution of catches from year to year could be another indicator of population tendency.

For each specie, median, mode and mean length values have been calculated both for the entire population and for population without recruitment.

Mean length value is strong influenced by recruitment magnitude and recruitment magnitude depends on specie reproductive period, growth rates, trawls selectivity. In addition, a change of 15 days in reproductive period or in survey sampling period could influence the abundance of recruits number.

If recruitment is excluded and just adults are considered, the influence of recruitment variability on mean length calculation is reduced.

Table 2 reports *Merluccius merluccius* values. Considering all catches, each potential indicator shows high variability: mean ranges between 125 to 170 mm, mode between 80 to 170 mm and median between 105 to 160 mm; all three indicators show almost the same trend. The same indices shows less variability excluding recruitment: in fact mean changes from 160 to 195 mm, mode from 125 to 170 mm and median from 140 to 180 mm. Generally mean and median but not mode have similar trend.

In Table 3 Red mullet values are reported. For the whole population, mean ranges between 105 to 140 mm, mode between 50 to 140 mm and median between 100 to 135 mm. For the adults mean changes from 120 to 140 mm, mode from 110 to 140 mm and median from 115 to 135 mm. Also for this specie, generally mean and median show the same trend during time.

In Table 4 Norway lobster values are reported. Calculated for the whole population the mean of carapace lengths distribution ranges from 26 to 34 mm, the mode from 22 to 38 and median from 22 to 32; if specimens under 20 mm of carapace length are excluded, mean values change from 28 to 36 mm, mode from 22 to 38 mm and median from 24 to 34 mm. During 2000 and 2002 years, when spawners density are at the lowest standard, mean, mode and median show the highest values both for the adult fraction and for the whole population.

It seems that when population density decrease, size increase rather than decrease as often it is supposed. Maybe this fact is related to specie biology and catchability. It is an aspect to investigate

Table 5 reports European squid values. Each indicator shows high variability and two distinct groups of year are evident: higher lengths in the first five years and lower lengths in the following five years. This fact shows that when population have a low number of density (from 1994 to 1998) mean lengths are highest and when density increase, mean length decrease showing a trend similar to Norway lobster one.

4. Discussion

The try to individuate potential indicator easy to understand for fishery management using data collected during ten years trawl surveys in the Northern and Central Adriatic shows some clear points and some points to investigate.

Northern and Central Adriatic sea shows different environmental features. In the Italian territorial water and in the international part of this geographical region, is present a wide continental shelf suitable for trawl fishing activity. Deep increases moving towards to east part in which demersal stocks are less exploited. For these reasons it is difficult to determine the exact extension of the area useful to calculate indicators that describe condition of resources and then use them to define Reference Points.

Total number of specimen per km^2, calculated using different area extension, shows a very wide range of values.

This density index referred to the entire GSA17, in which there are both areas characterised by a great fishing exploitation and areas, in the eastern part, with moderate fishing activities, is generally higher than that referred to the North and Middle Adriatic area, nevertheless they shows the same trend over the period covered from Medits surveys.

In order to determine indicators suitable for Italian fisheries management and considering that indexes calculated for the whole GSA17 shows the same trend of that calculated for the Italian territorial and international waters (i.e. the area in which Italian Fishing-boats carry out their activities), we decided to consider North and Middle Adriatic Sea area excluding Slovenian and Croatian territorial waters.

Analysing the time series of density index referred to the entire population it is possible to observe a large variability in the values obtained for each species. This is due to the variability in recruitment. So total density seems to be of difficult application in fishery management as indicator. It seems more useful to consider the density index calculated considering the spawning stock separated from the recruitment one.

Recruitment density give interesting indications, first of all about variability of this fraction of population. For some species such as hake, it seems to be a good estimator of recruit year per year.

In the case of other species, recruitment indicator has to be better calibrated both as limit size and verifying born period by age determination. The knowledge about born period can be useful to define annual variation in recruitment limit size. In fact during the years there are different growth rates and changes in reproductive period that influence the potential limit size.

The spawning stock density index shows a more stable temporal trend over the period covered by Medits surveys, and for some species (i.e. European hake and European squid) it is possible to use these values to establish warning level value for fisheries management.

In the case of Red mullet seems that values obtained in ten years allow population renewal also with successive high recruitment. Norway lobster shows some problems about catches representative; in fact catches seem to be more influenced by specie catchability than by the real abundance and composition of population. More investigations on this aspect are necessary.

Ratio between recruitment and spawners of previous year for some species suffers of the problem to evaluate recruitment. Recruitment sampling is not complete although a trawl with a mesh size (20 mm) smaller than commercial net has been used. Values are always very low and variable, showing no parallelism between spawners and recruitment: in fact a good recruitment could derive from a little number of spawners and a low recruitment could derive from a high number of spawners. It seems that, from processed data, there isn't a constant relationship between spawners and recruitment.

Mean, mode and median of lengths values both calculated on the whole sampling population and calculated only on adults fraction present some aspects that don't let to do theoretical consideration.

It would be expected a reduction of population magnitude presents a reduction of mean length values because the greater total mortality cause the reduction of largest size classes, but for two species as Loligo vulgaris and Nephrops norvegicus the contrary is verify. In the years when density of these species is lowest there is an increment of mean length. A theoretical investigation is required. This fact could be explain either with a different catchability or with different growth rates of intermediate sizes as consequences of abundance variations. More investigation would be necessary to test the suitability of these indicators.

As a general rule, the approach to the Reference Points determination using some biological indices, such as density indices for spawning stock, calculated from ten years data collected in the Northern and Central Adriatic sea area during Medits surveys, seems to be a very good starting point in order to obtain values easy to understand from fishermen. Nevertheless and it is necessary to improve the analysis of these biological indexes to tests the effectiveness in using Reference Points derived from these in fisheries management of demersal stock.

5 Conclusions

The most important premise to make a Reference Point an effective management tool is that fishermen and other participants in fishery could understand the meaning of that Reference Point.

Reference Points derived from monitoring density indexes variability calculated subdividing population according to the size composition, are more easy to assimilate for fishermen and for other non-technical operators. Moreover fishermen could verify the indication given by researcher during their fishing activities.

These indicators are very easy to calculate and it is possible to determine confidential limits for each one.

Based on data collected during ten years surveys, it is possible to indicate a range of value that can describe a condition without risks in compromising species stock biomass. Under the minimum value of that range a management response, which has been previously negotiated with the participants in fishery, is automatically triggered. The management response could be applied to certain areas or during certain periods.

The same approach could be applied to each commercial species obtaining a series of Warning Value.

If several density indexes, calculated for each species, go contemporaries under their corresponding Warning Value the management response will be more restrictive inducing to avoid fishing activities in the worse case.

Fisheries management has to be based on several indicators considering economic, social and biological aspects *inter alia*. Concerning the biological ones, the most understandable and easy to calculate is the estimation of the fish abundance.

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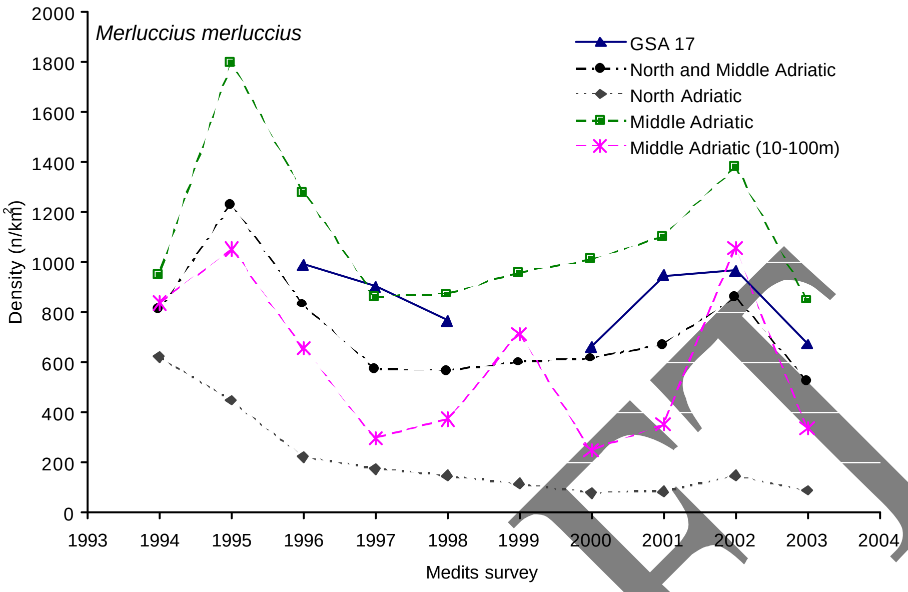

Figure 1: Trend of density indices of *Merluccius merluccius* in different areas.

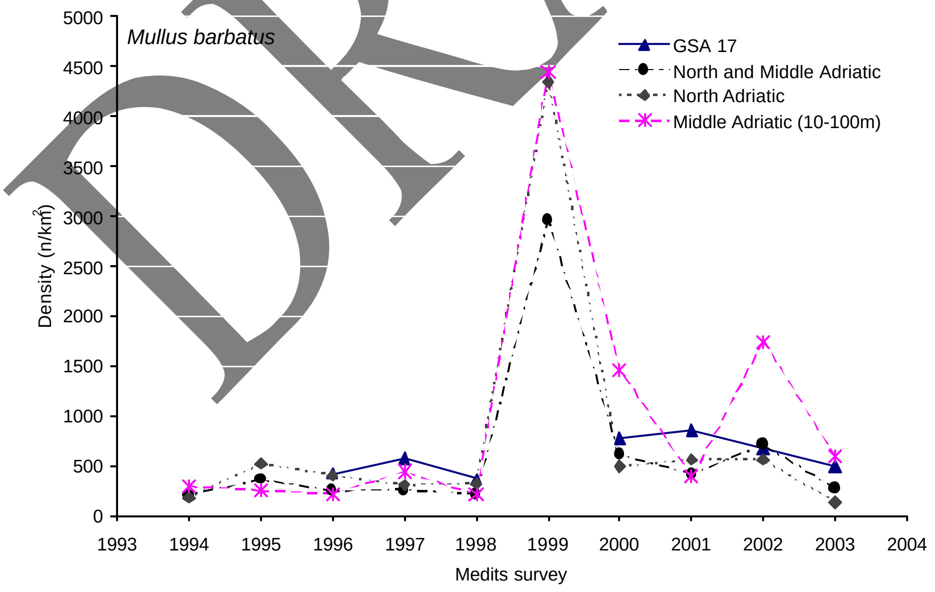

Figure 2: Trend of density indices of *Mullus barbatus* in different areas.

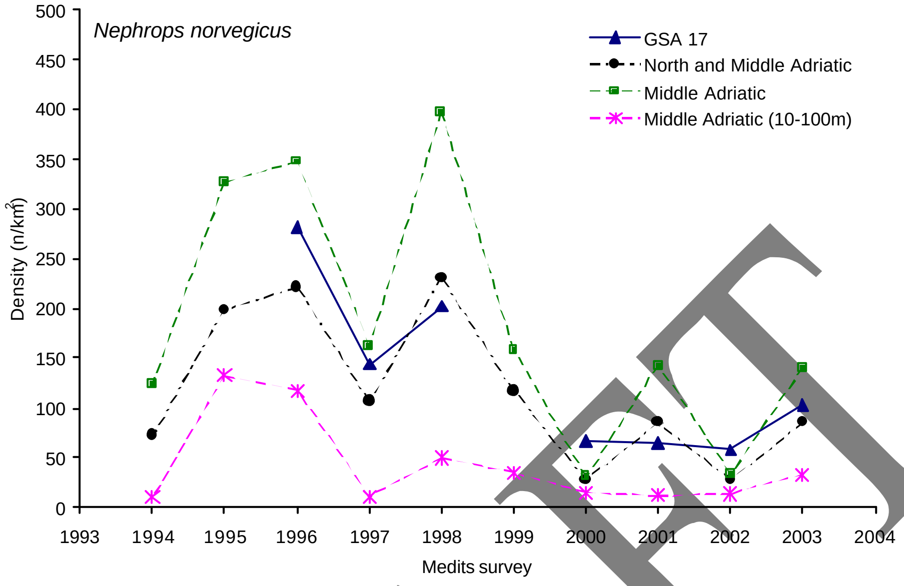

Figure 3: Trend of density indices of *Nephrops norvegicus* in different areas.

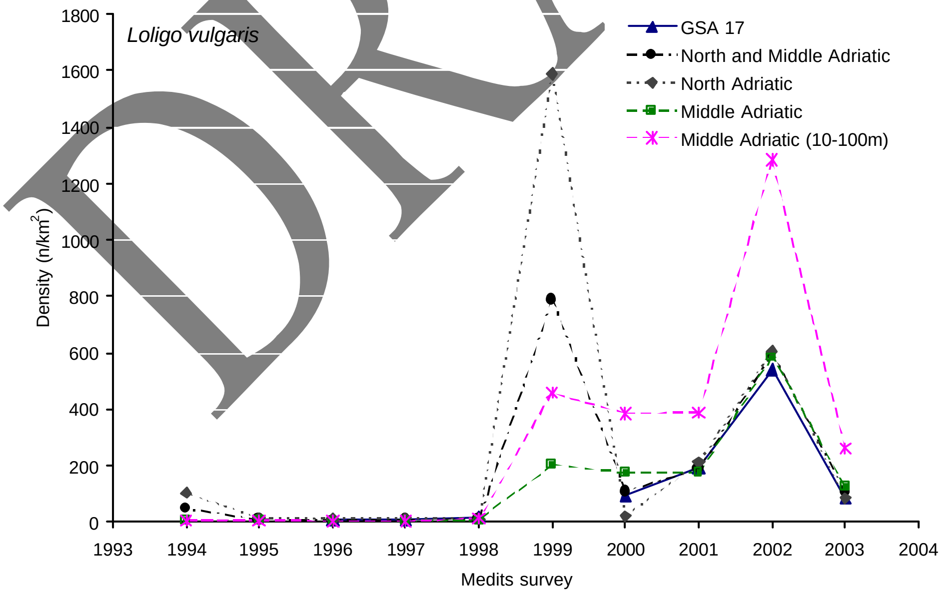

Figure 4: Trend of density indices of *Loligo vulgaris* in different areas.

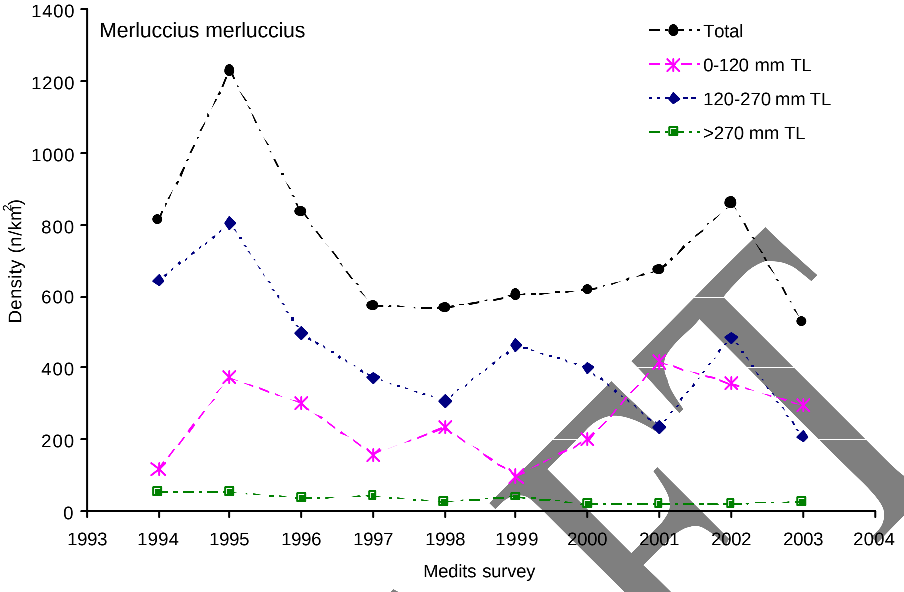

Figure 5a: Trend of density indices of the entire population, recruitment, intermediate class and spawning stock of *Merluccius merluccius* in the North and Middle Adriatic area.

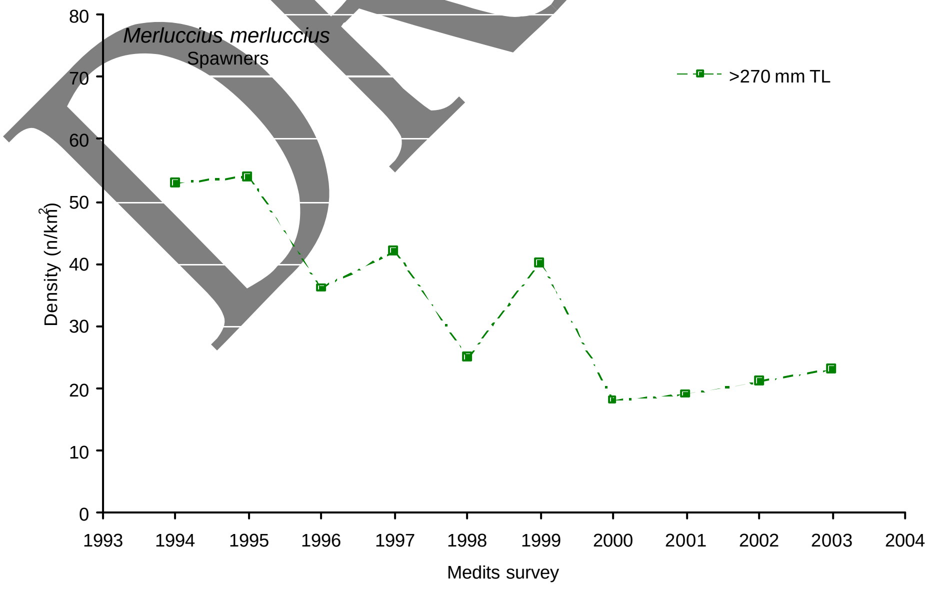

Figure 5b: Trend of density index of spawning stock of *Merluccius merluccius.*

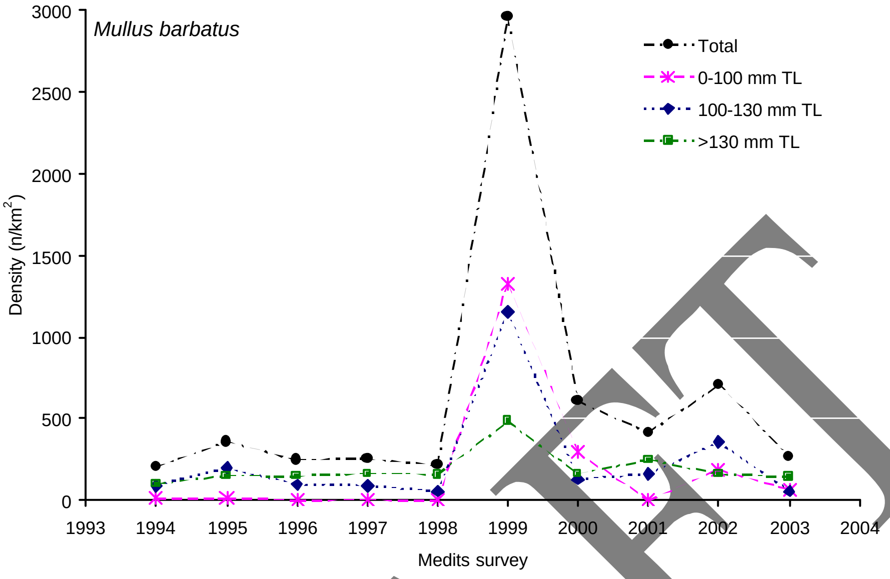

Figure 6a: Trend of density indices of the entire population, recruitment, intermediate class and spawning stock of *Mullus* in the North and Middle Adriatic area.

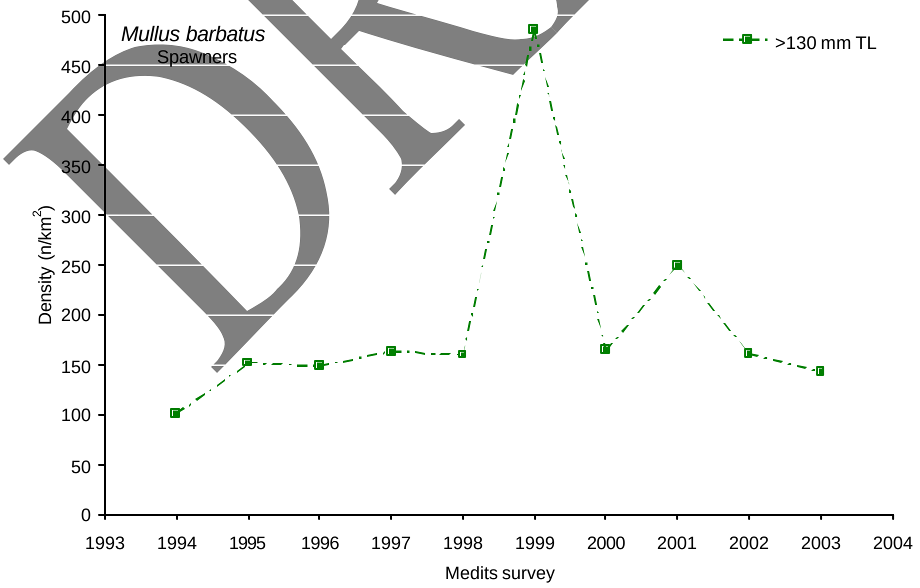

Figure 6b: Trend of density index of spawning stock of *Mullus barbatus*.

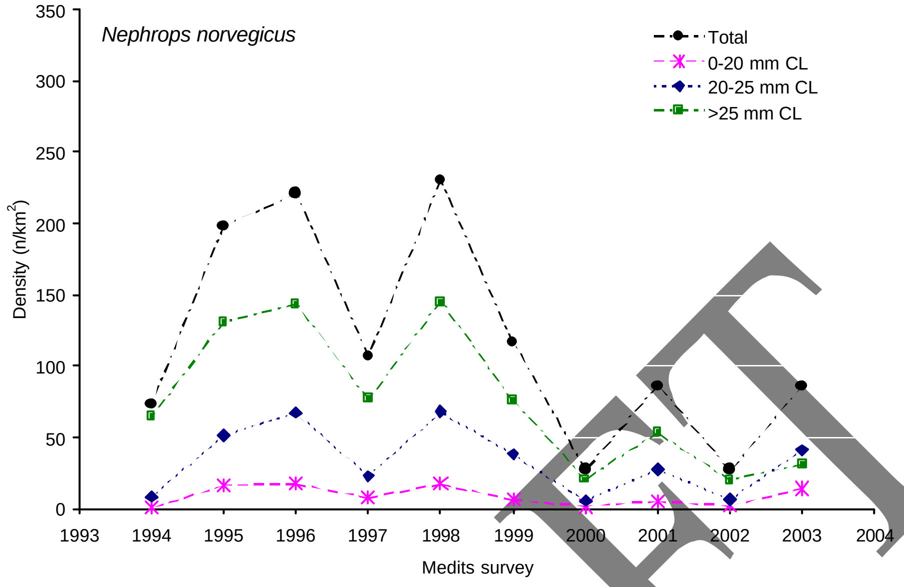

Figure 7: Trend of density indices of the entire population, recruitment, intermediate class and spawning stock of *Nephrops norvegicus* in the North and Middle Adriatic area.

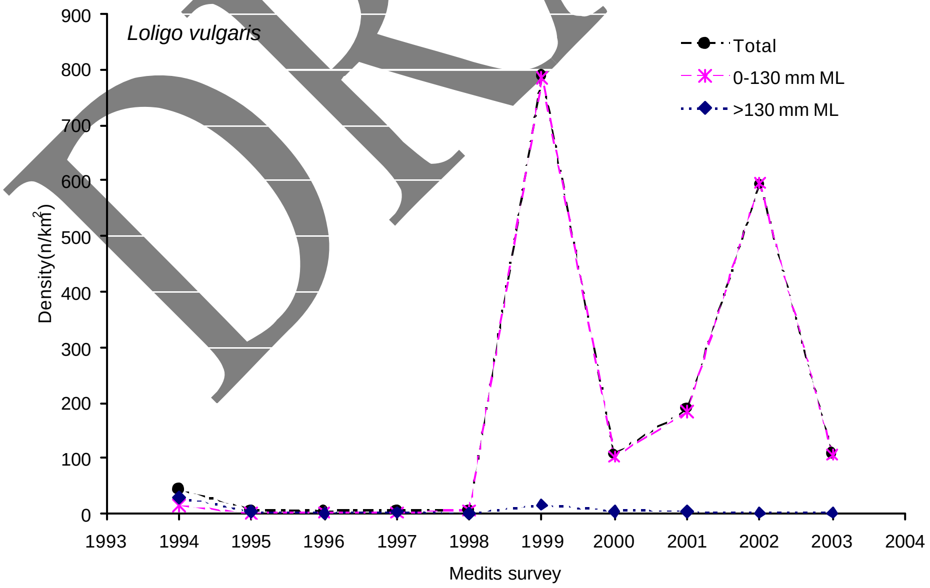

Figure 8: Trend of density indices of the entire population, recruitment, and adults of *Loligo vulgaris* in the North and Middle Adriatic area.

Table 1: Ratio between recruitment of one year and spawners of the previous year.

Recruitment/Spawners	**M. merluccius**	**M. barbatus**	*N. norvegicus*	*L. vulgaris*
R 1995 / S 1994	7.10	0.11	0.25	0.00
R 1996 / S 1995	5.52	0.01	0.13	0.41
R 1997 / S 1996	4.36	0.03	0.05	0.53
R 1998 / S 1997	5.58	0.004	0.22	1.01
R 1999 / S 1998	3.92	8.31	0.04	263.20
R 2000 / S 1999	4.95	0.61	0.02	1.11
R 2001 / S 2000	22.73	0.01	0.24	11.29
R 2002 / S 2001	18.57	0.76	0.03	26.17
R 2003 / S 2002	13.84	0.42	0.71	2.83

Table 2: Mean, mode and median values (mm) for size distributions of *Merluccius merluccius.*

	Total			Adults		
Medits surveys	Mean	Mode	Median	Mean	Mode	Median
1994	155	130	150	165	130	155
1995	155	190	150	155	190	150
1996	80	20	85	130	160	115
1997	125	/	125	145	/	140
1998	70	35-40	60	120	95	105
1999	70	70	70	115	95	105
2000	65	70	60	125	95	115
2001	55	50	50	120	95	110
2002	55	50	55	105	95	100
2003	60	60	60	115	100	100

Table 3: Mean, mode and median values (mm) for size distributions of *Mullus barbatus*

	Total			Adults		
Medits surveys	Mean	Mode	Median	Mean	Mode	Median
1994	135	120	130	135	120	130
1995	130	120	120	130	120	125
1996	135	130	130	135	130	130
1997	135	130	135	140	130	135
1998	140	140	135	140	140	135
1999	105	90	100	120	110	120
2000	105	75	100	135	130	130
2001	135	130	130	135	130	130
2002	110	115	110	125	115	115
2003	120	50	130	140	130	135

Table 4: Mean, mode and median values (mm) for size distributions of *Nephrops norvegicus.*

	Total			Adults		
Medits surveys	Mean	Mode	Median	Mean	Mode	Median
1994	30	30	30	32	30	30
1995	28	24	26	30	24	28
1996	28	24	26	30	24	28
1997	30	26	26	30	26	28
1998	28	26	26	28	26	26
1999	30	24	26	30	24	28
2000	34	38	32	36	38	34
2001	28	22	26	28	22	26
2002	34	24	32	36	36	34
2003	26	22	22	28	22	24

Table 5: Mean, mode and median values (mm) for size distributions of *Loligo vulgaris.*

	Total			Adults		
Medits surveys	Mean	Mode	Median	Mean	Mode	Median
1994	170	150	155	180	150	160
1995	155	80	150	185	160	170
1996	145	170	150	185	170	170
1997	165	170	160	195	170	180
1998	145	100	135	185	170	170
1999	170	130	150	185	130	165
2000	140	120	130	160	130	145
2001	125	95	105	185	125	165
2002	135	115	120	160	125	140
2003	130	80	110	185	130	175

LOOKING FOR REFERENCE POINTS IN THE MEDITERRANEAN SWORDFISH FISHERY

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Key words: *Ligurian Sea, reference points, longline, swordfish, recruitment index, CPUE.*

Introduction

The Ligurian Sea probably represents the sole Mediterranean area in which limitations to fishery activities in offshore waters have been enforced. In fact the main fishing grounds of the swordfish (Western Ligurian Sea, fig. 1) are now included in a "Cetacean Sanctuary" recently established on the basis of international agreements (2001); moreover since 1990, the Italian governement introduced a ban of swordfish driftnets (spadare) in order to protect pelagic life in the area. The ban mainly succeeded in stopping foreign vessels which used to arrive in summer in the Ligurian Sea to complete their fishing season started in Southern Tyrrhenian and Sicilian waters; from 1992 the ban was completely enforced in the protected area, i.e. included the small resident fleet.

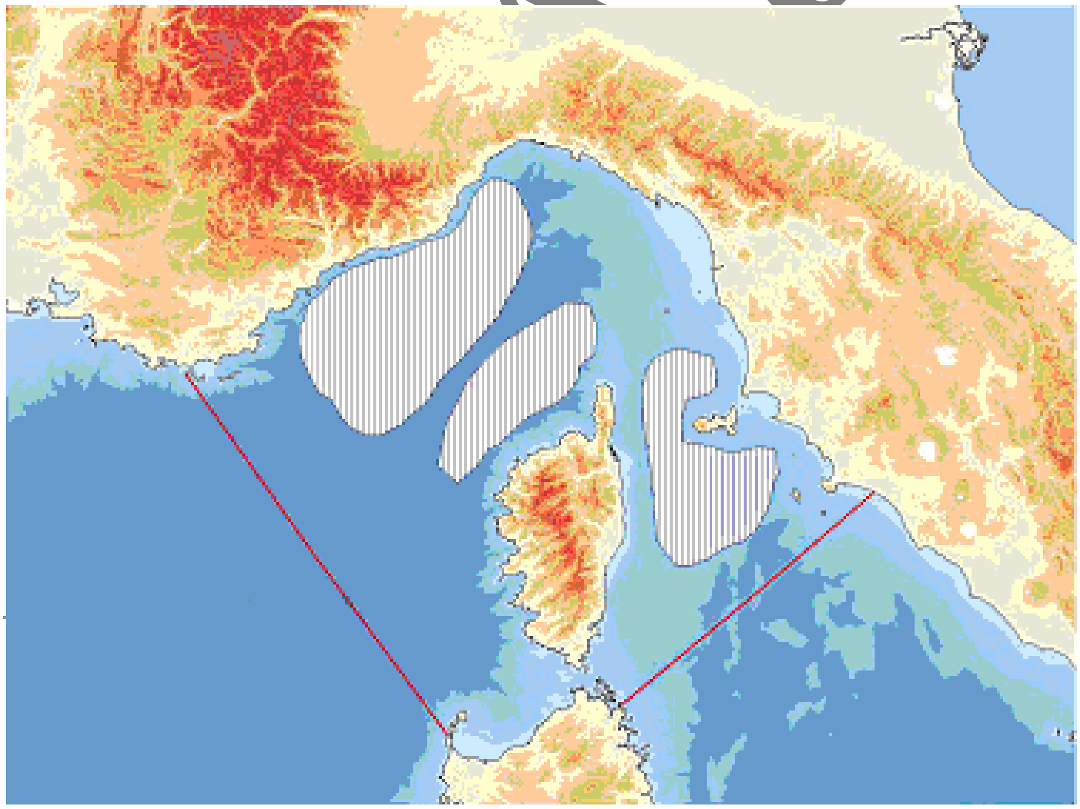

Fig. 1- The Cetacean Sanctuary of the Ligurian Sea and the main swordfish fishing areas of the local fleet.

Studying the biology and fishery of swordfish in the Ligurian Sea in the framework of national programmes of assessment, we have measured both CPUE and recruitment indexes from 1990 onward. These two set of data are assumed to be important reference points for this fishery: aim of this note is to present the trends of such indexes in our study area, the Ligurian Sea, and study possible relationships between them.

Materials and methods

Swordfish fishery activities have been monitored yearly in the main harbour of Sanremo and Imperia, which produce about 90% of the landings of the Ligurian coast. The fishing season goes from June to December and the most important gear commonly used in the study area is swordfish longline.

At landings, fish were measured (LJFL) and weighed (gutted weight, GW) to obtain length and weight-frequency distributions. CPUE in number and weight per 1000 hooks of swordfish longline were calculated.

According to ICCAT SCRS the recruitment index of the swordfish in the longline fishing is intended as the N of fish aged 1, caught by 1000 hooks (Mejuto, 1999; 2000; 2001; 2003 a-b).

To calculate the recruitment index on the Ligurian material, only fish caught during the period July-September, which represents the main part of the fishing season, were considered; given that the recruitment of the young of the year occurs in autumn, the first modal group in such summer l/f distribution should be represented by the fish of age 1. De facto it was so in the majority of 14 (1990 - 2003) summer l/f distributions; however in some years, e.g. 2003 in fig. 4, also a small group of fish of 0 group appeared; this fish was overlooked.

On the basis of Battacharya's method (Gayanilo *et al.*, 1994), both the first and the second age group were isolated in l/f distributions of each year, from 1990 onward, and related to the effort which produced the fish of each l/f distribution; the identification of such age groups was made on the basis of a growth function previously obtained in the study area (Orsi Relini *et al.*, 1999).

Summing up we have calculated the following CPUEs:

CPUE (N):	number of fish / 1000 hooks
CPUE (W):	weight of fish / 1000 hooks
CPUE (age 1):	number of fish aged 1 / 1000 hooks = recruitment index
CPUE (age 2):	number of fish aged 2 / 1000 hooks

Results and discussion

a) *Total CPUE in weight*

This index represents the most direct measure of the fishing yeld. In the study area its trend resulted positive (fig. 2).

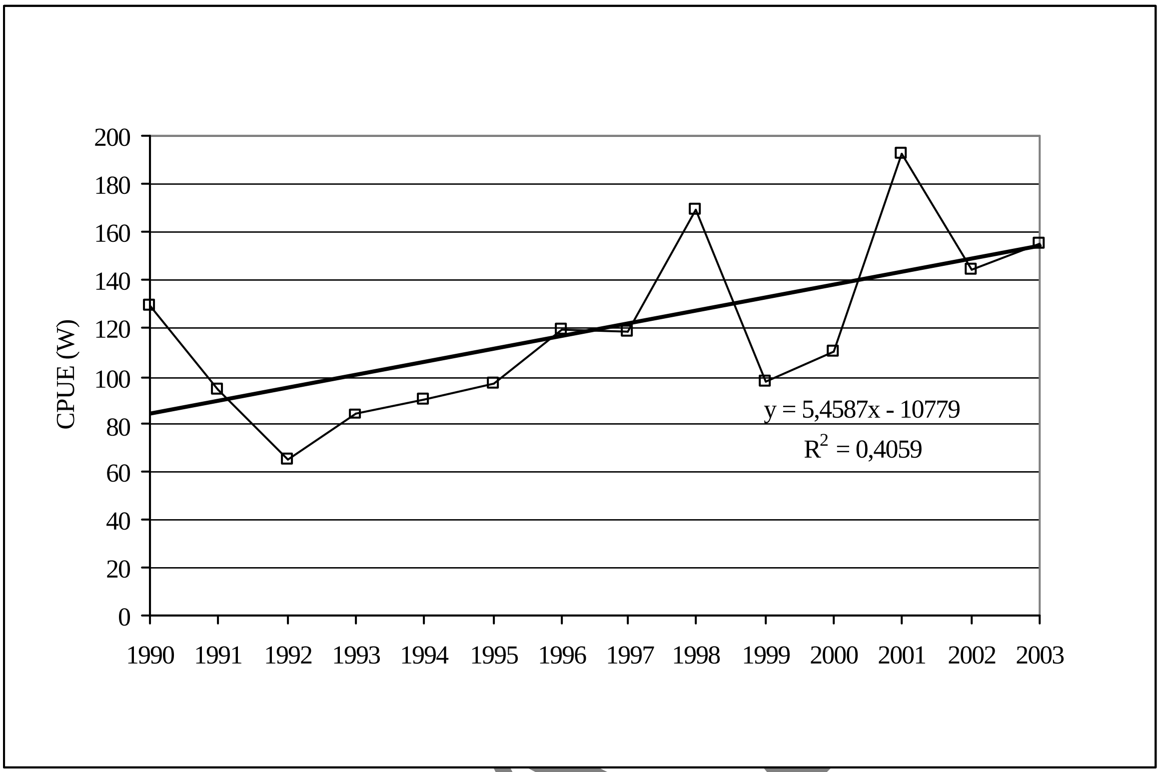

Fig. 2 – Trend of CPUE (W) of the swordfish caught by longlines in the Ligurian sea.

In detail, it is possible to observe a negative trend in the catches between 1990 and 1992; after 1992 catches were regularly increasing till 1997; between 1997 to 2002 the catches were also growing, albeit with large fluctuations. The indicated overall trend, significant at a = 0.01 (99 %), represent an important amelioration of the catches.

It is interesting to verify if the increased catch is due to more numerous or to larger swordfish. The CPUE (N) (fig. 3; significant trend for a = 0.01) shows that the fish caught by 1000 hooks increased in number from about 3.5 to more than 7, while the average size was scarcely changed (see also the weight increase in fig.2). So if we assume a previous state of overfishing, to which the protection of the area represented a remediation, it more probably was a recruitment overfishing than a growth overfishing.

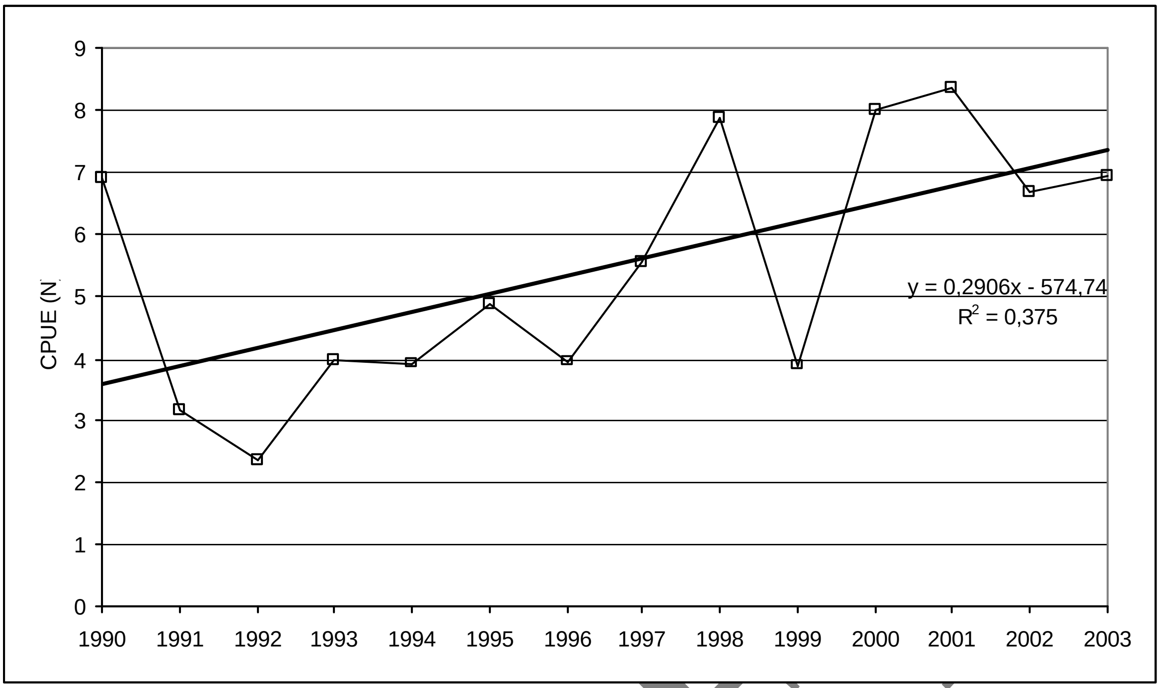

Fig. 3 – Trend of CPUE (N) of the swordfish caught by longlines in the Ligurian sea.

b) Recruitment index

In the period 1990 – 2003 the values of CPUE (age 1) ranged between a minimum of 0.4 and a maximum of 4.5. The temporal sequence is shown in fig. 4.

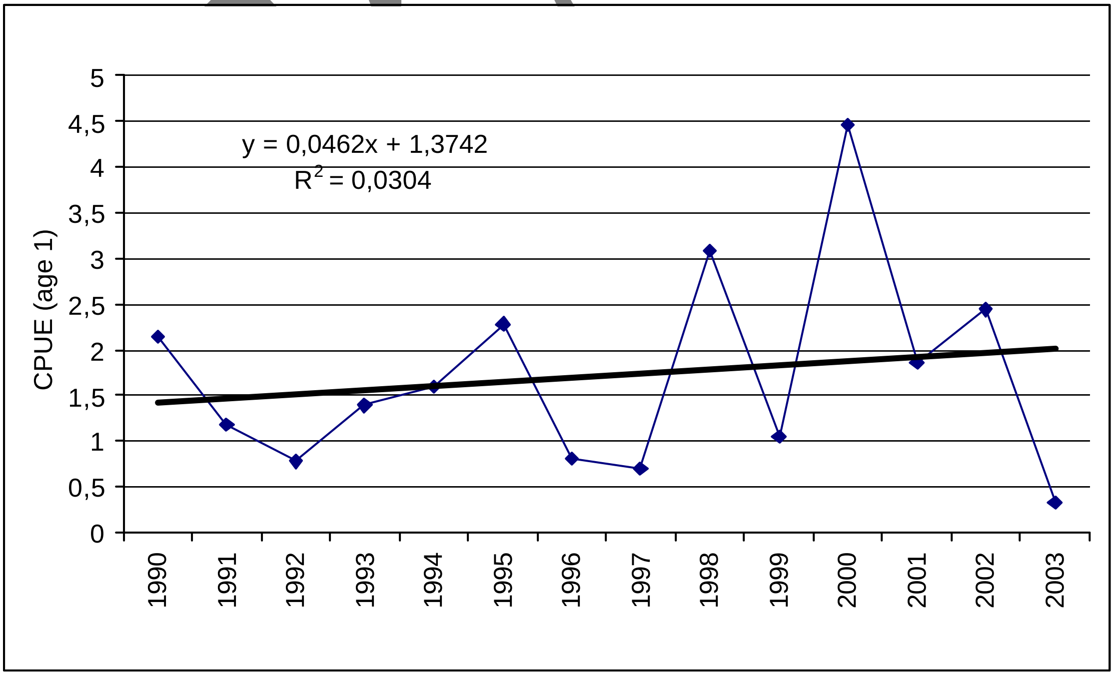

Fig. 4 – Trend of the recruitment index (CPUE of fish of age 1) of the swordfish caught by longline in the Ligurian Sea.

The recruitment index appears to have not a trend: there are several oscillations around an average value (1.72; dev. st. 1.11); since 1997 such oscillations are annual. It is interesting to verify these features in the l/f distributions (fig. 5): a relevance of the first cohort, i.e. age 1 fish, with modal length of about 95 cm LJFL, occurs alternately with that of larger fish (modal length 115 cm LJFL or more). In other words each recruitment pulse can be traced in the following year by means of the abundance of fish aged 2; in fact the two yearly abundances of the same cohort of fish are significantly related (fig. 6; a = 0.01).

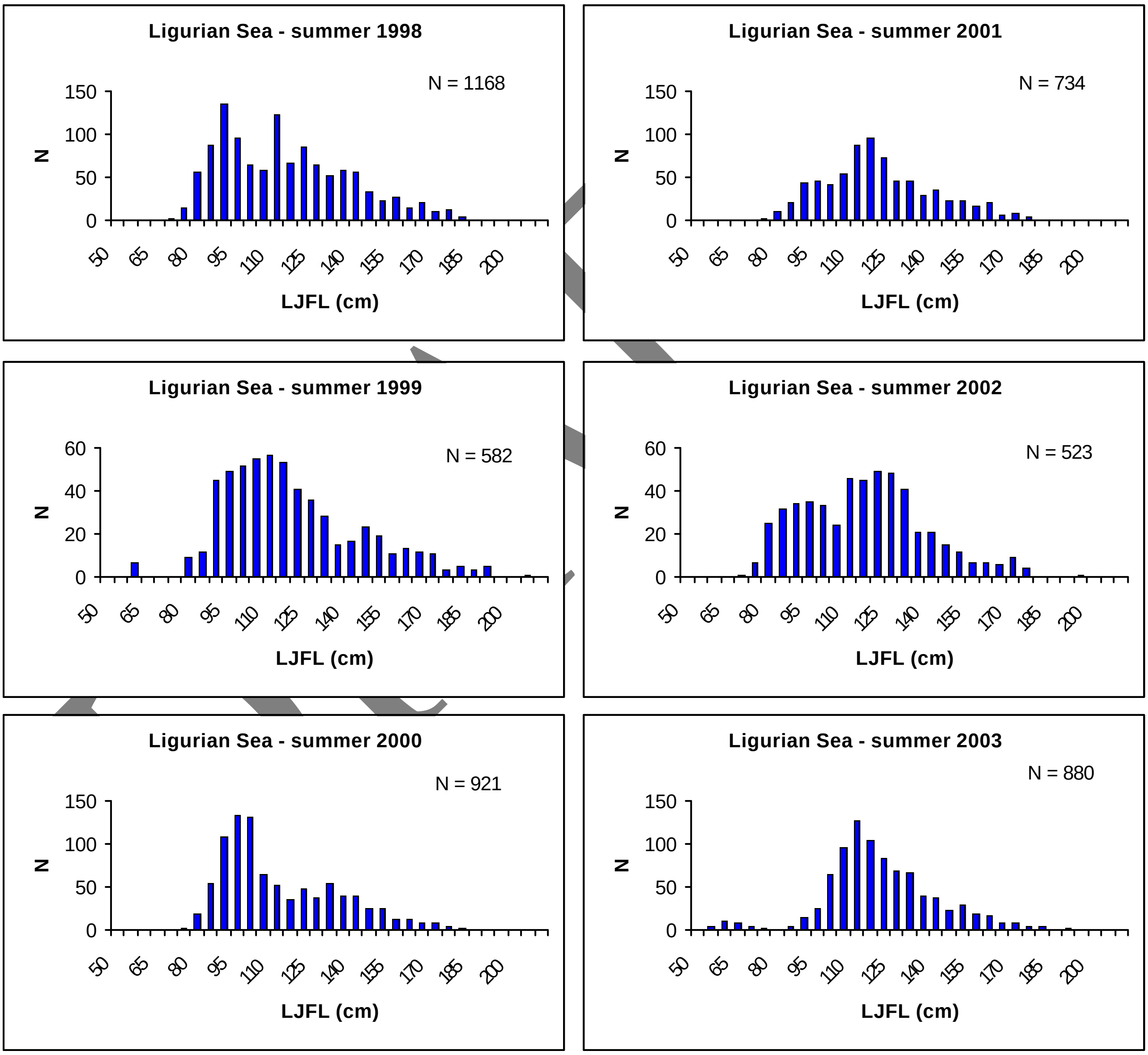

Fig. 5 – Length frequency distribution of swordfish summer catches from 1998 to 2003.

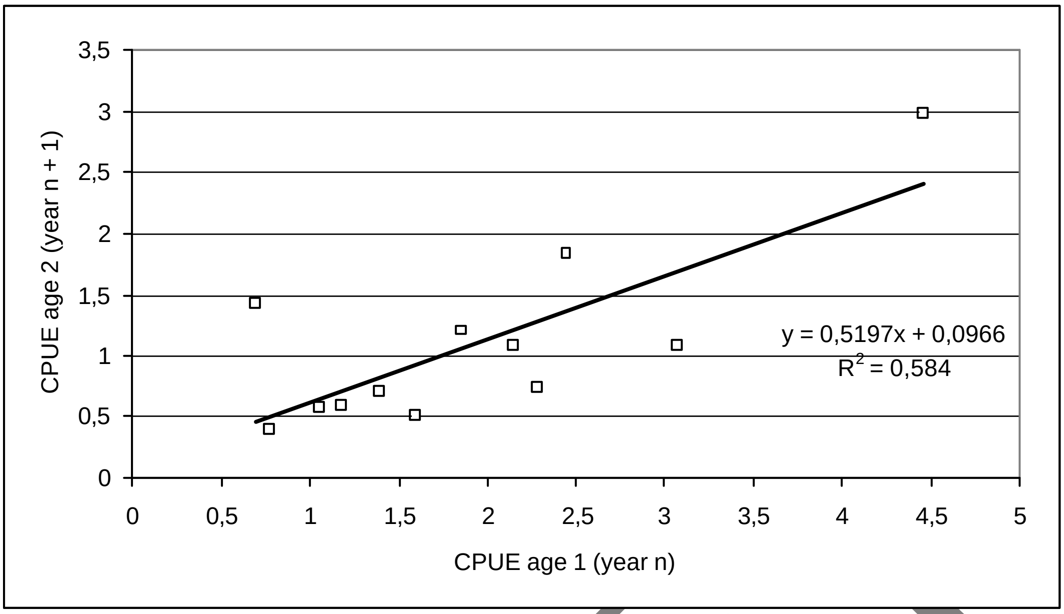

Fig. 6 – Correlation between the CPUE (age 1) and CPUE (age 2) of the following year, in the longline catches of the Ligurian Sea.

Given the absence of a linear trend, can the recruitment be considered as stationary? Probably no. The recruitment can also be described by a polynomial function (fig. 7) in which two periods can be separated: a first period, when the recruitment is scarce and a second in which the recruitment is more abundant.

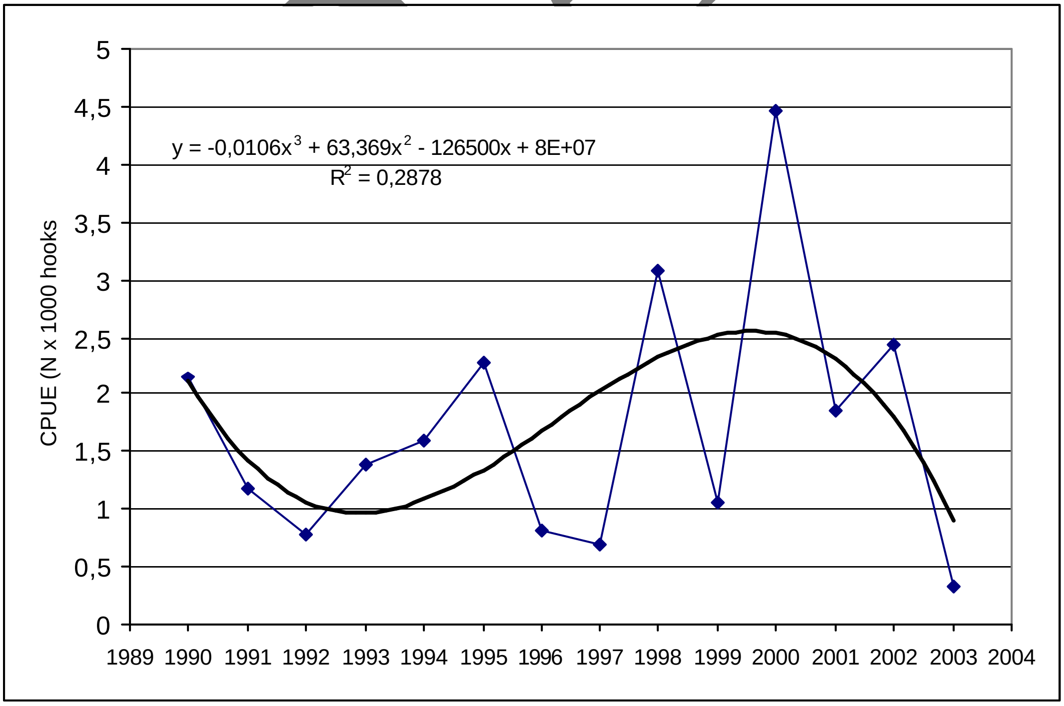

Fig. 7 - Recruitment index (CPUEn of fishes of age 1) described by a polynomial function.

Positive effects in the fishery are delayed to the second period. In fact the swordfish has a long life and a late sexual maturity in the female. In the study area the L_{50} resulted 149 cm LJFL, which corresponds to an age of 4 years and ages up to 11 years were observed in females (Orsi Relini *et al.*, 2003; Rollandi *et al.*, 2004). Probably, after recruitment, some years are necessary to obtain significant biomasses. In the present series of data, if a delay of 3 years is introduced between CPUE W and the recruitment indexes, the two temporal sets appear positively related (fig. 8; significant R^2 for a = 0.05).

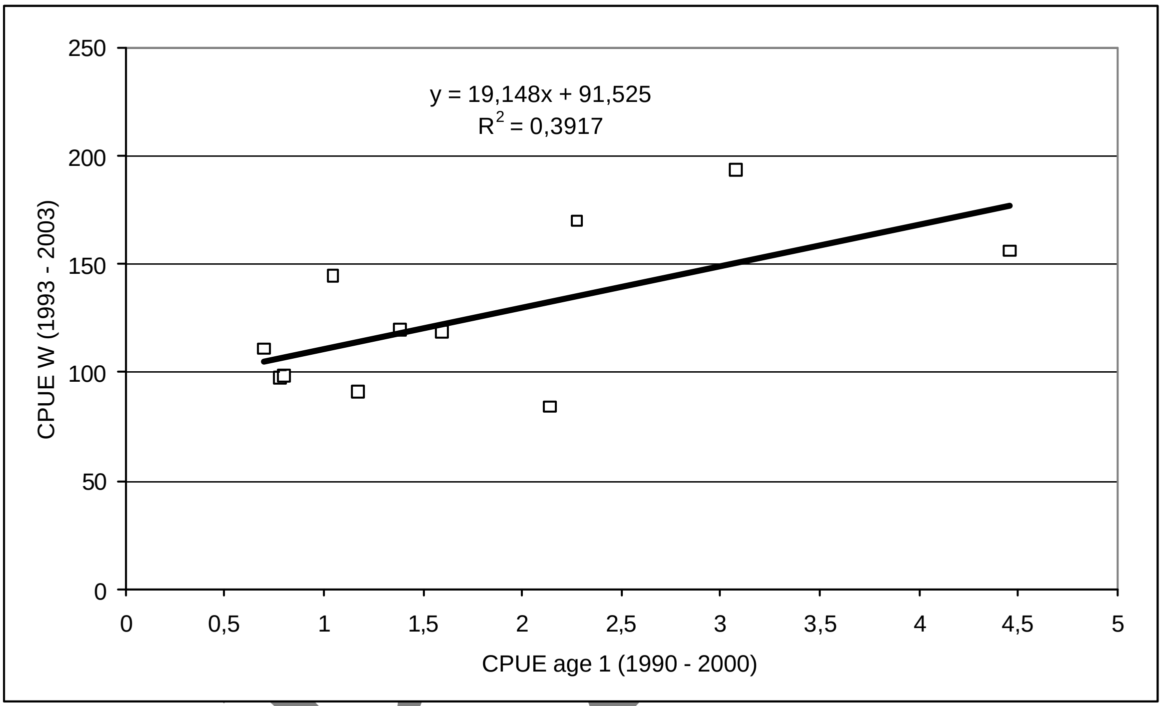

Fig. 8 – Correlation between the CPUE (age 1) and CPUE (W) recorded 3 years after, in the longline catches of the Ligurian Sea.

In conclusion, having assembled data series regarding two basic reference point of the swordfish fishery in a continuum of 14 years, we have tried the first inferences. We are of the opinion that only with the prosecution of similar studies, these first attempts will gain firmness and possibly their predictive value shall be verified.

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LES POINTS DE REFERENCE: UN NOUVEL APPROCHE POUR LA GESTION DE LA PECHE ITALIENNE

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Summary

In the recent years many increasing difficulties are evident in the management of the fish stock and fishery. It is necessary a critical review of the methods used for the determination of the state of stocks, of the rules adopted to manage the fishery, of the reaction of the fishermen and finally of the results obtained.

The more important factors of these difficulty are:

- poor quality of data base
- improperly utilisation of few models
- monospecific approach
- low consideration of basic principles of ecology, for i.e. prey predators, mortality density dependent, variability of recruitment, effects of abiotic factors, etc.
- fishing effort estimated with large imprecision
- fishermen and public opinion have difficulties to understand the workers language in fishery science
- low confidence of the fishermen’s in the advice of scientist and international commission on the state of the stocks, without practical confirmation
- long time is necessary from advice to implementation of protection measures
- oppositions of the fishermen to observe measures without their involvement.

The list of limiting factors is longer.

A new approach for stock and fishery management will be based on:

1) individuation of few indicator of the stocks state and fishery, easy to understand for fishermen and realistic, i.e. quantity of fish at sea, total index and species index, the spawners index, economic income of a standard vessel, etc.
2) It is necessary to establish two values for each indicator, the reference points: the fishery continues without new rules over the upper limit value, a situation of attention starts under the first limit value. Alarm reference point is a second value of the same indicator; when the value is touched, new rules in fishery enter in force.
3) The monitoring plan include the collaboration with the fishermen organisations when the first limit value is touched.
4) A list of operational units will be established for every G.S.A.
5) A preventive definition of a group of measures for operational unit will be established. These measures will be implemented automatically when the alarm reference point will be reached.
6) The measure are graduated in relation to the situation. The measures involve the gears, the technical measures, the closure of fishing area, the reduction of fishing time, the reduction of operative fleet and, at the end, the stop of the fishery.
7) The extraordinary limitation of the fishery will be expire when values of references points will be normal.

This approach has the advantage to be easy to understand for all, in addition it acts in the specific way and in due time, with consensus of the fishermen.

Key words
Fishery indicators, Fishery management, Italian Sea, Reference points

Introduction

Dans la gestion des stocks et de la pêche deviennent toujours plus évidents les limites des méthodologies utilisées soit pour évaluer la situation des ressources que pour l'aménagement de la pêche. La situation est complexe et une révision critique du problème entier s'avère nécessaire a la lumière des résultats négatives des approches utilisées jusqu'à maintenant.

Différents analyses critiques sur des sujets spécifiques ont été menées, le livre vert de l'Union Européenne résume une certain nombre des situations.

Les éléments qui déterminent la faiblesse des approches actuellement utilisées a niveau internationales et nationales sont nombreux, les principales sont:

1) faible qualité des données de base sur: la flottille totale, la répartition par engin de pêche, le temps de pêche, les quantités rejetées en mer, la répartition par taille des captures etc.;

2) l'utilisation des modèles, sans vérifier si les conditions où les ipotéses a la base des modèles soient accomplies;

3) faible considération de la forte variabilité de réclutement et de la mortalité naturelle, en particulier pour les espèces a vie courte ou moyenne;

4) faible considération des principes basilaires de l'écologie, par ex les relations avec les facteurs abiotiques, la disponibilité et les passages d'énergie dans la chaîne alimentaire, le rapport entres espèces, en particulier proie/prédateur, la mortalité naturelle densité dépendante etc.;

5) l'approche monospeciphique, toujours utilisé, mais qui ne reflète pas la réalité;

6) difficultés de déterminer l'effort de pêche totale et celui appliqué sur chaque espèces et/ou communauté;

7) pécheurs et opinion publique qui ont des difficultés a comprendre les langages utilisées par les biologistes de pêche quand sur des base de données peu fiables faut des élaborations trop poussées;

8) faible considération des pécheurs des avis des scientifiques et des organisations internationales, quand il ne peuvent pas avoir une confirmation pratique sur l'abondance de la ressource en mer;

9) temps trop long nécessaire entre l'occurrence de situations négatives, la prise de décisions sur les mesures et l'application sur le terrain;

10) faible respect et opposition des pécheurs a chaque mesure de gestion prise sans la participation active des organisations des pécheurs.

La liste des faiblesse pourrait être plus étendue, mais ces aspects sont suffisant pour commencer a chercher un approche différent, avec une vision plus générale du problème.

Situation de la pêche italienne

La production de la pêche italienne en 2003 a été de 582600 Tonnes, pour une valeur d'environ 1900 Millions d'Euro (IREPA, 2004). Les captures de la pêche en Méditerranée, sans considérer les bivalves et l'aquaculture, sont de l'ordre de 312000 Tonnes avec une augmentation des captures vis-à-vis de l'année 2002 (303900) de 8000 Tonnes.

La flottille qui a opéré en Méditerranée en 2003 est de 15602 bateaux, avec un tonnage de 178000 Tonnes; cette dimensionne de la flottille est le résultat d'une action de soutien a la réduction de la capacité de pêche qui dans la période 2000-2003 a éliminé en Italie 1630 bateaux pour un tonnage de 24500 Tonnes. Cette situation a comporté une réduction de plus de 8000 pécheurs en trois ans, diminution influencée aussi par les améliorations technologiques et actuellement il y a seulement 38000 pécheurs.

La rétribution moyenne pour ces pécheurs est d'environ 11400 Euro par an, et une partie des pécheurs, actuellement provienne d'autres Pays.

Le nombre de jour de pêche dans l'année 2003 est différente par catégorie des bateaux et par engin de pêche; les chalutiers, qui sont le bateaux de plus grande taille ont péché en moyenne en 2003, 170 jours et les chalutiers pélagiques 153 jours. Il faut souligner que la longueur d'une journée de pêche est différents, en fonction du tonnage des bateaux et des conditions locales; seulement pour quelques groupes des bateaux la journée de pêche a une durée de 24 h., la plupart des bateaux relise des sortie d'environ 10 heures et une partie de ce temps est nécessaire aux déplacements pour arriver au lieu de pêche et revenir au port.

La valeur des captures est très variable, en fonction des espèces, de la qualité et des quantités pêchés. Plus grande est la capture, plus faible est le prix unitaire. Avec une capture plus abondante augmente le travail pour les pécheurs et il est nécessaire augmenter l'équipage.

Le tendance de la politique nationale est d'arriver a stabiliser l'occupation, la flottille, les captures et d'augmenter le revenu, la responsabilisation des pécheurs et de leurs organisations dans la gestion de la pêche et l'aménagements des ressources est le passage choisi.

Des exemples positifs existent dans la pêche italienne, la gestion de la pêche aux petits praires avec plus de 700 bateaux intéressée où les organisations «Consorzi Gestione Molluschi » déterminent sur base territoriale les jours de pêche, la quantité a capturer dans chaque journée, les zones de fermeture, les périodes de fermeture, les activités de redistribution de la ressource et collaborent avec les autorités pour le contrôle du respect des règles.

La recherche estime les quantité de petits praires en mer, leur distribution, les tailles etc. et informe en continuation les organisations des pécheurs des éléments nécessaires a la gestion.

Actuellement a niveau nationale et a niveau de l'Union Européenne les mesures de gestion, ont la principale limitation dans la faiblesse des données de base, et dans la situations des pêcheries multi espèces; l'effort de pêche est reparti sur une large groupe d'espèces capturée ensemble. Dans la pêche italienne il n'y a pas aucune espèce qui représente le 10% des captures et une seule espèce, quelque fois deux, arrivent au 5%.

Les mesures prises sans la participation des organisations des pécheurs ont une adesion très faibles, souvent les pécheurs adoptent tous les artifices possibles pour éviter l'application.

Nouvel approche

Il est fondamentale que toutes les mesures de gestion prises par les administrations a différents niveaux, soient expliquées et partagées par les sujets qui doivent les respecter. Dans ce sens les résultats des évaluations de l'état des stocks réalisés par les scientifiques devront être exprimées en terme faciles a comprendre concrets et vérifiables sur le terrain. Il faut choisir ensemble une liste d'indicateurs de l'état des ressources et de la pêche; quelques indicateurs pourrons prendre en considérations des aspects socio-économiques, d'autres indicateurs seront d'ordre biologique sur les principales espèces, ou mieux, ensemble d'espèces. Il sera possible ajouter d'autres indicateurs dans le temps.

Les indicateurs de départ pourront être:

a) quantité de poisson en mer, estimée d'une façon standardisée pour quelques espèces de chaque communauté. L'index pourrait être estimée en kg/km² ou N/km²;
b) quantité de reproducteurs pour les mêmes espèces, exprimée un N/km²;
c) réclutement, c'est-à-dire numéro de poissons qui entre dans la pêcherie chaque an, pour les mêmes espèces;
d) revenu économique de différents métiers, pour des bateaux standardisés;
e) composition par taille des mêmes espèces avec une taille moyenne.

Les indicateurs choisis et les valeurs limites pour chaque indicateur, seront etablì en accord entre l'administration, les organisations des pécheurs et la recherche. Il est clair que les valeurs limites fixées servent pour éviter un collapse et non pour établir le niveau optimal des captures de chaque espèce. Les institutions de recherche dans les différents domaines, déterminent, chaque an, les valeurs des indicateurs pour chaque sous zone en étroite coopération avec la profession. Un accord est discuté préalablement, pour fixer les règles nouvelles a introduire, quand un ou plusieurs points d'alarme sont dépassés. Ces règles peuvent intéresser une ou plusieurs zones, un ou plusieurs engins de pêche, des mesures techniques, des périodes de fermeture, des zone fermées etc.

Quand le plan de monitorage montre que la valeur pour un indicateur, dépasse le point de référence entre la normalité et le niveau d'attention, les pécheurs sont informés et ensemble on suit l'évolution de la situation. Si la situation arrive au point de référence d'alarme, le Comité de gestion est informées et de façon automatique les limitations a la pêche déjà discutées et acceptées entrent in vigueur. Quand la valeur de l'indicateur récupère et revient dans les valeurs d'attention ou de normalité, les limitations terminent et la partie de la flottille concernée par les limitations, reprenne l'activité normale.

Pour avoir un bon système d'intervention, une liste des unité opérationnelles pour les principales zones ou on exerce la pêche, pourra être etabliée. La liste des UU.OO. pourra servir pour avoir des mesures qui touchent directement et seulement le secteur géographique, l'engin de pêche et les espèces en danger de collapse. Une participation des pécheurs a la mise au point du système, pourra être utile pour le respect des règles.

Le schéma du processus est reportée dans le tableau.

Application a la pêche italienne

Dans le cas de la pêche italienne ce nouvel approche peut considérer une situation de départ dans la quelle quelques points sont déjà réalisés.

L'Administration nationale, les organisations professionnelles et la recherche scientifique composent le Comité Nationale de Gestion de la Pêche. Ce comité, éventuellement légèrement modifié, devrait définir les indicateurs convenables et fixer les points de référence d'attention et d'alarme. Les zones d'aménagement ont été définie sur le plan international (CGPM-FAO) et sont 7 zones géographiques.

Les Unités Opérationnelles ont été établies dans le cadre de la coopération internationale (AdriaMed) pour une zone géographique, la méthodologie est fixée et il faut l'appliquer aux autres zones géographiques italiennes.

Les travail plus important a faire c'est la fixation des mesures a adopter dans chaque zone géographique et les UU.OO. concernées en fonction des indicateurs.

Le programme de monitorage existe déjà a niveau nationale et il est basé sur le Règlement de l'U.E. n° 1543 et considère soit les aspects biologiques que socio-économiques, il est commencé en 2002.

Il y a deux campagnes de chalutage par an dans les 7 zones, l'échantillonnages des captures et la récolte des paramètres socio-économiques.

Pour des ressources partagées entre différents Pays le même approche pourrait être adopté, avec la variante que au lieu du Comité de Gestion, il y a l'Organisation Internationale avec les Pays concernés.

Quand pour les indicateurs établis les valeurs d'attention ou d'alarme soient dépassés, l'Organisation Internationale informe les Pays et adopte ou demande l'adoption, des mesure déjà établies en fonction des accords avec les Pays.

Considérations générales

Cet approche a la gestion de la pêche en Italie pourrait avoir des avantages, en premier lieu faire participer les professionnels a la gestion des ressources. Dans chaque aire géographique il serait possible former des groupements de professionnels avec la même licence de pêche pour la gestion d'une pêcherie, dans quelques cas il y a des Organisations des producteurs. Connaître et comprendre les problèmes est la base pour les résoudre.

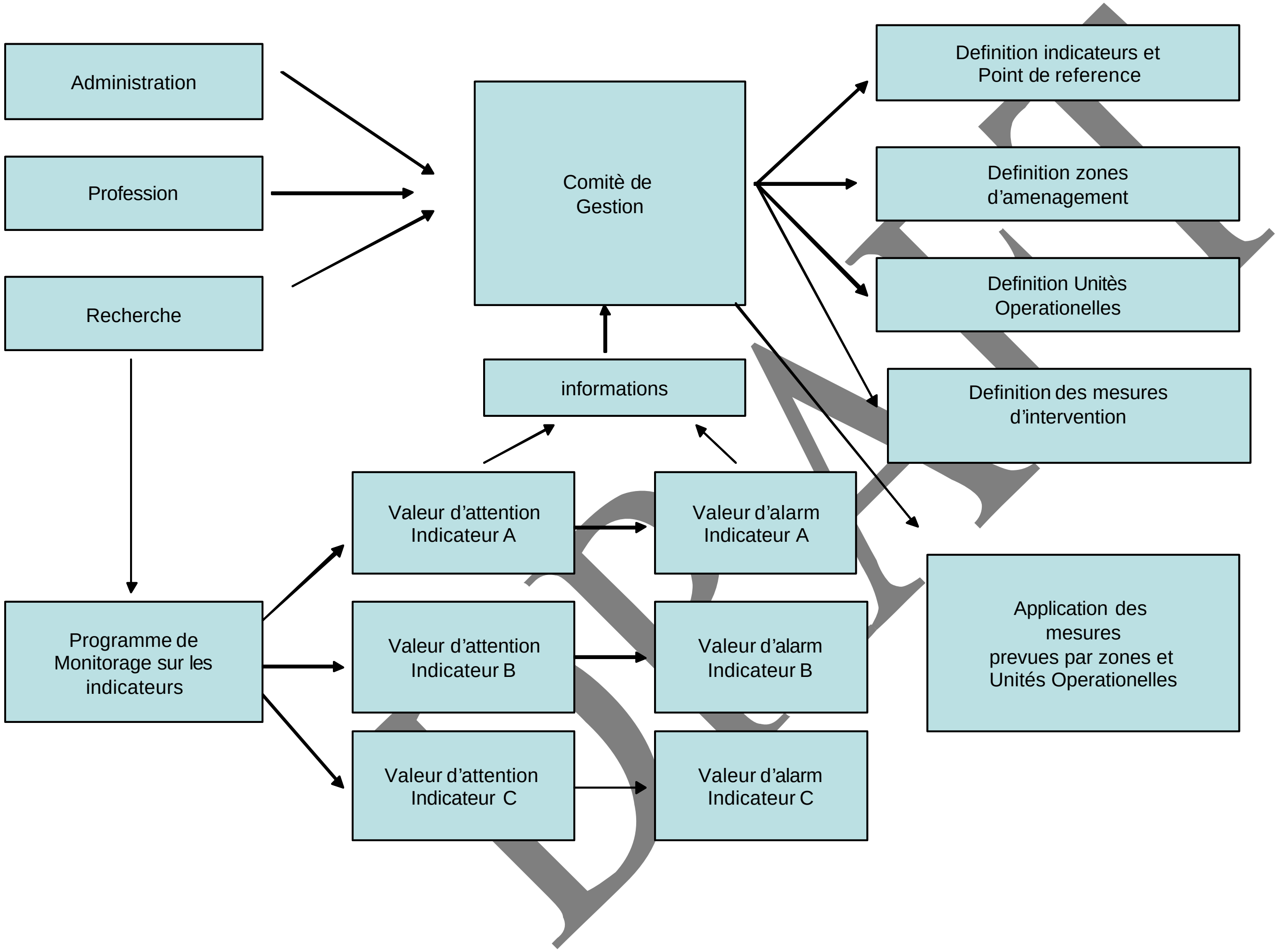
En deuxième lieu le temps qui passe entre la constatation d'une situation de possible danger, vérifié sur le terrain, et la mise en œuvre de mesures appropriés, est rapide et pourrait être plus efficace.

La discussion des mesures a prendre se développe sans être dans une situation urgente et dangereuse, et peut être plus facile et fructueuse.

La recherche scientifique change son rôle, il n'est plus nécessaire élaborer, ou appliquer, des modèles pour arriver a un rendement optimale pour chaque espèce, mais la recherche prend la responsabilité de contrôler les valeurs des indicateurs. La recherche aura la tache de dialoguer avec les pécheurs, expliquer les situations, vérifier ensemble aux professionnels ce qui se passe en mer et suivre avec les principales acteurs le déroulement des situations, moins de théorie et plus de dialogue.

Les administration auront la coordination et le contrôle de toute la procédure, avec des problème mineures pour le respect des normes.

Pour les stocks partagés, une fois trouvé l'accord sur les indicateurs, les points de référence et les mesures a prendre, l'Organisation Internationale compétente, pourra adopter les mesures acceptées ou demander l'adoption aux Pays concernés en fonction de ses propres Statut, avec des taches claires.


Administration
Profession
Recherche
Comitè de Gestion
informations
Definition indicateurs et Point de reference
Definition zones d'amenagement
Definition Unitès Operationelles
Definition des mesures d'intervention
Application des mesures prevues par zones et Unités Operationelles
Programme de Monitorage sur les indicateurs
Valeur d'attention Indicateur A
Valeur d'alarm Indicateur A
Valeur d'attention Indicateur B
Valeur d'alarm Indicateur B
Valeur d'attention Indicateur C
Valeur d'alarm Indicateur C

APPLICATION OF BIOLOGICAL REFERENCE POINTS: ANALYSIS OF THREE DIFFERENT LEVELS OF *ARISTAEOMORPHA FOLIACEA* EXPLOITATION

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Abstract: In this paper we undertook to explain the temporal evolution of a deep-sea, economically important resource, *Aristaeomorpha foliacea* (Risso, 1827), whose exploitation has changed considerably over the last ten years, owing to the increase of the fleet. Our investigation centred on three geographical areas of Sardinia and highlighted how some models react to the change in fishing effort. Through our investigations, we seek to contribute to the definition of a correct reference point. Using the Beverton and Holt model for the three zones, it was possible to identify the value of Fmax as LRP and the $F_{0.5}$ as TRP.

Keywords: assessment, *Aristaeomorpha foliacea*, red shrimp, reference points, Sardinian seas.

1. Introduction

The state of natural renewable resources and their sustainability over time was the focus of the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro, Brazil, in 1992. The event reflected a “global desire for a more ecosystem-based sustainable development across all sectors of human activity” and it recommended a “substantial shift in governance, a substantial increase in strategic information and an improved scientific support in decision-making” (FAO, 2000).

Despite the scientific advice, at the Rio de Janeiro Conference two years later, in the “Review of the State of the World Marine Fisheries Resources”, which updates previous information about fisheries stocks, it was reported that several demersal resources of northern continental shelves had suffered a dramatic decline (FAO, 1994).

With reference to the Mediterranean Sea, the FAO sources concluded that (FAO, 1997), it was “one of the few marine areas of the world's oceans showing a steady increase in production for all major resource categories”. However, a certain amount of apprehension for resources such as the red shrimp and hake remained, because of the increase in slope fisheries.

At a time when , throughout the Mediterranean sea, and in Sardinia in particular, deep sea resources are being heavily exploited, it is important to increase scientific research to assist with their management. One way to do this is through the establishing of accurate Reference Points (RPs), which has been a common theme of recent studies on Mediterranean stocks. The idea is to provide criteria for stock management - without which stocks would collapse - taking into account biological (growth, mortality, reproductive period etc.), technical (fishing effort, CPUE) and economic factors (Alemany and Álvarez, 2003, Carbonell and Azevedo, 2003, Maynou *et al.*, 2003, Ragonese and Bianchini, 1996).

In this light we undertook to explain the temporal evolution of a deep-sea, economically important resource, *Aristaeomorpha foliacea* (Risso, 1827), whose exploitation has changed considerably over the last ten years, owing to the increase of the fleet. Our investigation centred on three geographical areas of Sardinia and highlighted how some models react to the change in fishing effort.

In recent years, the Sardinian fleet, too, has undergone considerable transformation as a consequence of government incentives aimed at its modernisation. The main change has involved the replacement of the old, low-tonnage wooden boats with large deep-sea iron boats. As a result slope fisheries have progressively increased and, therefore, there has been a move of the fishing pressure toward deep-sea resources, which in the early nineties, were little exploited in the Sardinian seas.

Furthermore, since biomass index trends are also linked to the changes in the fleet in recent years, we analysed their evolution, too, in order to explain the situation for this important resource in the most comprehensive way. Through our investigations, we seek to contribute to the definition of a correct reference point.

2. Materials e Methods

Biological data was collected from between 1994 to 2003, and involved ten trawl surveys carried out in the seas around Sardinia, following the international MEDITS programme (Bertrand *et. al.*, 2000, 2002). In total, an average 32 hauls per year took place following a depth stratified random methodology. An experimental net (with 20 mm cod end stretched mesh size) was used in the survey. The hauls had an average duration of 1 h, and were carried out only during daylight hours at depths of between 201 and 800 m.

In this work we examined specimens of *A. foliacea* (Risso, 1827) collected between depths of about 388 and 720 m; for each haul, the shrimps were counted and weighed. After determining the sex, the carapace length (CL, mm) of each specimen was recorded.

The data processing involved identifying three sub areas with different levels of exploitation: the South-Eastern (Zone 1), Southern (Zone 7) and South-Western (Zone 6) parts of Sardinia (Fig. 1), giving a total of 236 hauls analysed.

The data for the Sardinian fleet in the years 1991 to 2000 came from the published data of the “Regione Autonoma della Sardegna”. To examine its evolution, it was divided into categories according to tonnage TGT (Tonnage of Gross Tonnage): 10-30, 30-70, 70-100, over 100 TGT.

Insert figure 1

Catch data (biomass and number of specimens collected) was processed in order to calculate abundance (number of speciments/km^2) and biomass indexes (kg/km^2), and related coefficients of variation (CV), according to the algorithms proposed by Cochran (1977) and explained by Souplet (1996) within the MEDITS programme. These indexes were compared by zone and year, using two-way ANOVA, after first evaluating the homogeneity of variance using Bartlett’s test. In case of heteroscedasticity, indexes were log-transformed (log (x+1)) before ANOVA, thus making the statistical analysis more robust (Zar, 1999). Pair-comparisons, based on both indexes, were made using the

Scheffè test and the statistical level was set at 0.05. Statistical analyses were performed with the *STATISTICA* package (release 5.1).

To distinguish the individual age groups of the length frequency distributions, we used the EM algorithm used in MULTIMIX (Murray and Hunt, 1999; Sabatini, *et al.*, 2002), then cohort analysis (Pope, 1972) was used to estimate the numbers at each age for each cohort. This analysis was developed on an excel spreadsheet.

Total mortality Z was estimated using the exponential decay model (Sparre and Venema, 1998). Observing the progressive decrease of the number of samples within the same age range each successive year, we estimate Z using the equation:

$$N_{t2} = N_{t1} \cdot e^{-Z(t2-t1)}$$

where

$$Z_{(t2-t1)} = -\ln\left(\frac{N_{t2}}{N_{t1}}\right)$$

As regards the natural mortality rate (M) we used Pauly's empirical formula (1980):

$$\ln M = -0.00152 - 0.279 \ln L_{\infty} + 0.6543 \ln K + 0.463 \ln T$$

which requires estimates of the von Bertalanffy growth parameters (L_8=70.7, K=0.538; Cau *et al,* 2002) and the mean environmental temperature (T=12.6°C). Fishing mortality rate (F) was obtained by subtracting M from Z.

The analytical models were processed in accordance with the "Beverton and Holt (Gayanilo *et al.*, 1996) yield per recruit model" where Y/R is considered a function of F and T_c (age at first capture, 0.85 y). Assessment of the fisheries' status was performed by comparing the mean fishing mortality rate for each year analysed and for each Zone, with different levels: F_{max} (the value of fishing mortality rate associated with the highest Y/R value for a given fishing strategy), $F_{0.1}$ (the value of F at which the slope of the Y/R is 1/10 of its value at the origin) and $F_{0.5}$ (the value of F associated with a 50% reduction of the biomass per recruit in the unexploited stock).

3. Results

3.1. Changing in fishing fleet

The south-eastern area of Sardinia (Zone 1), whose trawling surface is quite limited, was subject to heightened fishing pressure even before the fleet renovation. This was partly caused by the local boats but also by the fact that, whenever the Mistral wind blew, the majority of the southern fleet flocked into this area. The main reason for such fishing pressure was the number of middle-low tonnage boats, although these had a reduced capture capacity.

As a consequence of the overhaul of the fleet, Zone 1 had a rapid and notable increase in fishing pressure, mainly due to the boats of middle-high (70-100 TGT) and high tonnage (over 100 TGT), with increases of 125% and 200% respectively (Fig. 2). On the other hand, the smaller boats underwent a progressive decrease (Fig. 2 a).

Insert figure 2

In the southern area (Zone 7) exploitation was primarily the result of middle-high tonnage boats, and, for very low percentages, high tonnage vessels. After the renovation of the fleet, this Zone had a notable increase in high tonnage boats, reaching increases of 60-65% (Fig. 2 b), while middle-high tonnage boats evidenced a 50% increase.

Finally, the south-western area (Zone 6), before government incentives, was seen to be the least exploited, because of its larger trawling area and the forced break that the winds of the third and fourth dial imposed during the winter months. In this Zone, the main protagonists of fishing activity were the low tonnage boats (Fig. 2 c). The replacement of the boats and the great productive potentiality of this area, due to its low exploitation, led to a significant increase in fishing pressure, since a high percentage of the new middle-high and high tonnage boats flocked into this Zone. Thus, this area went from a situation of low exploitation, to one of overexploitation.

3.2. Abundance and biomass indexes

In order to analyse the way in which the red shrimp resource reacted to the increase in fishing pressure, we first analysed abundance and biomass rates in the three areas. What becomes immediately clear is the different index trends of the areas (Fig. 3). Zone 1 is the most highly exploited and shows the lowest values, both for abundance and biomass indexes, with mean values of 276 n/km^2 and 4.2 kg/km^2 respectively. Zone 6 and 7, on the other hand, areas with an increasing exploitation rate, show higher values for biomass and abundance indexes, with mean values of 11 and 12.2 kg/km^2 and 776 and 854 n/km^2 respectively.

From temporal analysis of the biomass indexes, it can be seen that in Zone 1 both biomass and abundance indexes (Fig. 3 a, d), already low in 1994, collapsed during the final two years (2002-2003). Zone 7, South Sardinia, (Fig. 3 b, e) shows an oscillating trend for the indexes over the years examined, reaching their maximum value in 1998 and then falling progressively until 2002. Finally, in Zone 6, (Fig. 3 c, f) both indexes were below the average until 2000 and achieved maximum productivity in 2002.

Insert figure 3

Bartlett's test indicated omoscedasticity for biomass indexes and heteroscedasticity for those of abundance. Statistical analysis using the ANOVA test (Tab. 1, 2) showed statistical differences ($P<0.05$) for both indexes, between zones ($P=0.011$ and 0.008), but not between years ($P=0.663$ and 0.450). Pair-comparison (Scheffè's test), too, evidenced statistical differences ($P<0.05$) for the comparison between Zone 1 with Zones 6 and 7 using both biomass and abundance index; no further differences were found in comparisons between years.

Insert table 1
Insert table 2

3.3. Trend of fishing mortality rate

Analysis of the demographic evolution in each Zone highlights the effects of fishing pressure. The results showed the progressive disappearance of older individuals, while the instant fishing mortality showed an increase in F for cohort 1^+ (Fig. 4). This can be seen in Zone 1, during the final two years in particular.

Insert figure 4

Observing average Fs (Fig. 5) we notice in Zone 1 two different trends. Until 1998 the values remained stable around 0.4 while in the final two years they increased dramatically reaching values higher than 1. In Zone 7, too, we notice two trends, but this time with F values lower than in the area previously examined. Until 1996 F was around 0.2; later it increased to nearly 0.4. These values are similar to those registered in 1994 - before modernisation - in Zone 1. Zone 6 showed values oscillating between 0.2 and 0.4 until 1996, then a sudden increase in the year 2000, with F=0.8.

Insert figure 5

Analyses done using the Beverton and Holt yield per recruit model and with evaluation of F levels, suggest that the resource is close to full exploitation. Thus, in Zone 1, until 1998, F values were between $F_{0.5}$ (0.31) and $F_{0.1}$ (0.46), the only exception being 1996, when the F value was 0.63, still lower than F_{max} (0.81), however. In the final two years (1999 and 2000) the highest values of fishing mortality rate among the three examined zones were recorded, with values higher than F_{max} therefore indicating a situation of overfishing. Zone 7, instead, for all the years examined, exhibited values lower than F_{max}, with the highest value recorded in 1999 (F=0.69). From 1994 to 1996 fishing mortality rates were lower than $F_{0.5}$; in the years following, F value increased, but nonetheless remained under $F_{0.1}$. In Zone 6 we registered the higher fishing mortality rate in the final year (2000), with a value of F (0.79) almost equal to F_{max} (0.81); previous years had F values lower than $F_{0.1}$, and in 1994, 1995 and 1998 lower than $F_{0.5}$ too.

4. Discussion

The definition of BRP (Biological Reference Points) for the Mediterranean, as recommended by the GFCM (FAO GFCM Report, 2003), highlights the need for urgent research into the state of fishing resources based on homogeneous indicators and in-keeping with this particular sea.

Considering that choosing these indicators, until now, has proved difficult, given the economic and environmental implications involved, in this work we try to evaluate the accuracy of several of the most commonly used analytical models, in three different areas of Sardinia. In these areas, starting from different initial situations of exploitation, we witnessed a transformation of the fleet which, in consequence, over time, led to a different fishing pressure on resources.

Zone 1, East Sardinia, turned out to be area suffering the most, both because of its reduced trawling surface and the fishing effort, which has increased considerably in recent years. The clear reduction in the biomass indexes and recorded value of fishing mortality rate higher than $F_{0.1}$ might be considered as a warning signal for the shrimp stock of this Zone, as in the final years examined the situation had worsened.

South-west Sardinia, Zone 6, has a bigger trawling area than that of Zone 1, and the increasing fishing effort is more evenly distributed over the area; however, this area, too, has suffered from this increase, with an increase in fishing mortality rates in the final years. The fishing mortality rate in this Zone gradually increased from 1994 and the attainment of a value equal to F_{max} in 2000 must be seen as an important sign of the state of the stock in this Zone.

South Sardinia, Zone 7 is that which suffered least from the increase in fishing effort in the zones analysed, due, among other things, to the typical turnover of gulfs. However, the reduction in biomass and abundance indexes recorded since 1998 and the slow increase in fishing mortality rate cannot be underestimated.

It is evident that the analysis of index trends alone does not allow us to draw a complete picture of the condition of resources. Only the analysis of data collected over long periods show reliable trends and, in extreme cases, demonstrate situations of quasi-collapse, as seen in Zone 1. On the other hand, such data, together with the analysis of analytical models can evidence the real situation more clearly. In our case study the analysis of the mortality per cohort rates demonstrated a progressive increase of F in favour of class age 1^+. This information has allowed us to show the effects of fishing pressure on individual age groups, demonstrating how, in the case of the red shrimp, catches are increasingly recruitment-dependent. The Beverton and Holt model was seen to be exhaustive. Using this model for the three zones, it was possible to identify the value of Fmax as Limit Reference Point (LRP). However, identification of the Target Reference Point (TRP) was more difficult. Analysis of the three island areas in which a rapid shift from the $F_{0.1}$ value to Fmax in only a few years was recorded, leads us to suggest $F_{0.5}$ as a value compatible with TRP.

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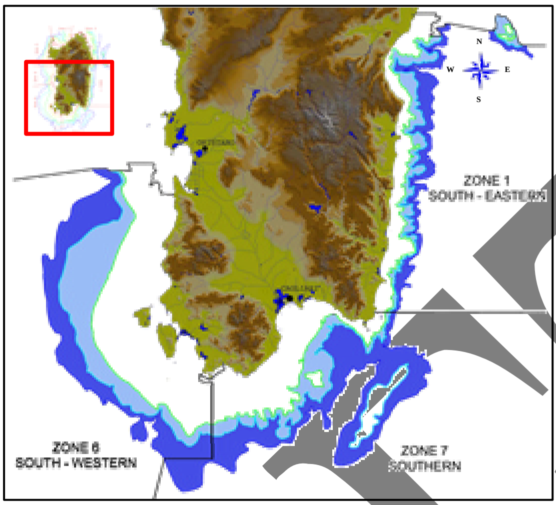
N
W
E
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ZONE 1
SOUTH - EASTERN
ZONE 6
SOUTH - WESTERN
ZONE 7
SOUTHERN

Fig. 1

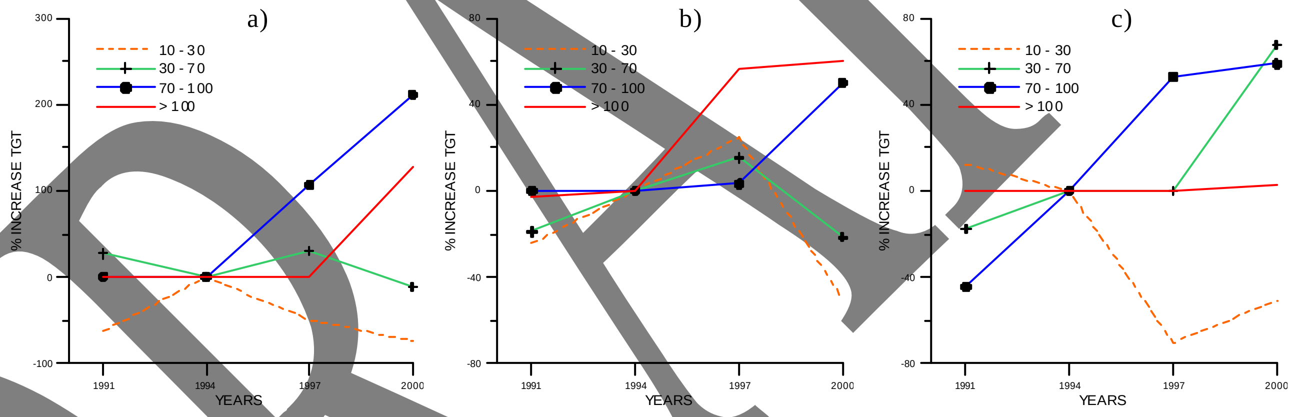

a)
b)
c)
10 - 30
30 - 70
70 - 100
> 100
% INCREASE TGT
YEARS
300
200
100
0
-100
80
40
0
-40
-80
1991
1994
1997
2000

Fig. 2

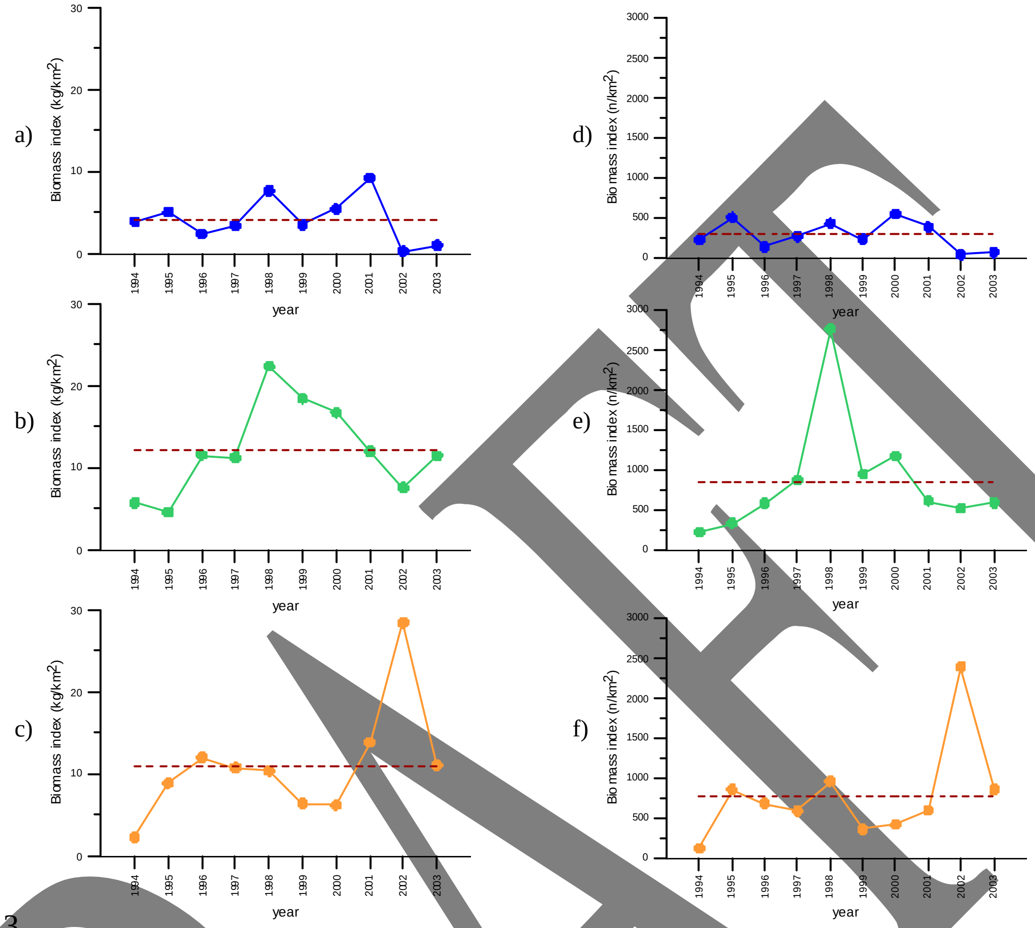


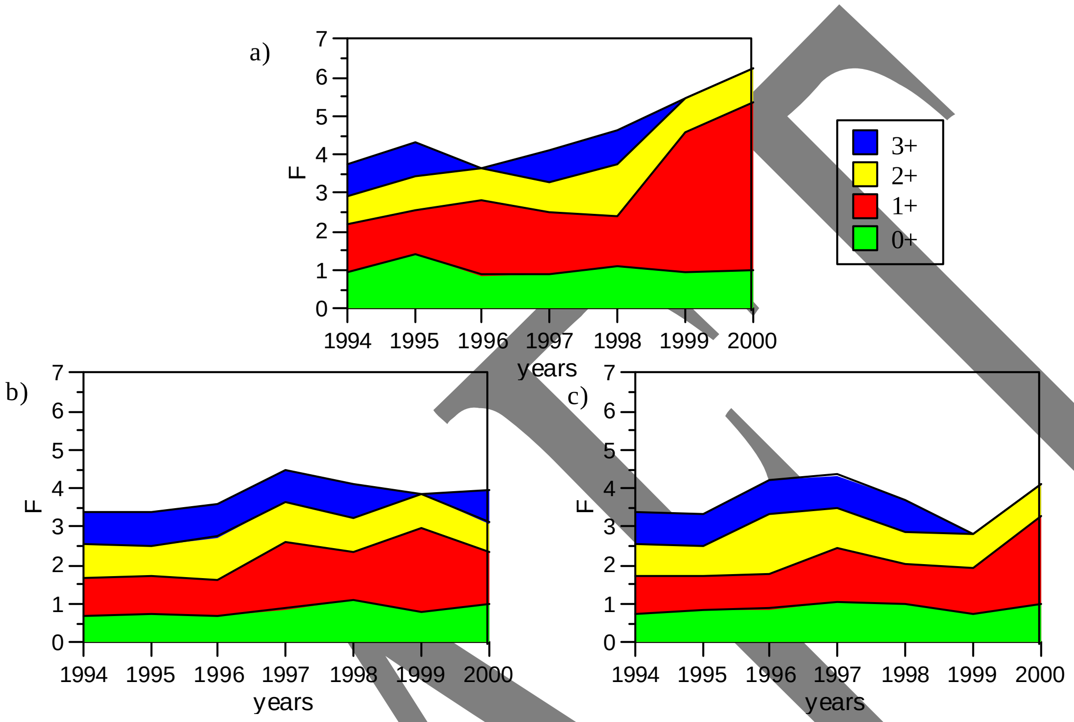
Fig. 3

Tab. 1

Source of variance	df	Sum of squares	Mean Square	F value	P Value
Zone	2	373.094	186.547	5.822	0.011
Year	9	215.503	23.945	0.747	0.663

Tab. 2

Source of variance	df	Sum of squares	Mean Square	F value	P Value
Zone	2	1.577	0.788	6.490	0.008
Year	9	1.134	0.126	1.037	0.450


a)
b)
c)
F
years
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1
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7
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1995
1996
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1998
1999
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🟥 1+
🟩 0+

Fig. 4

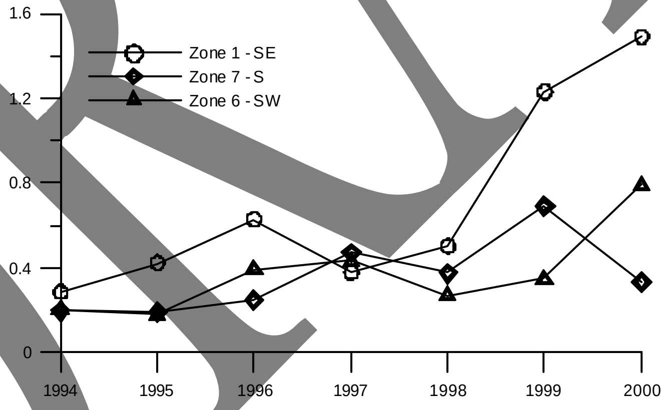
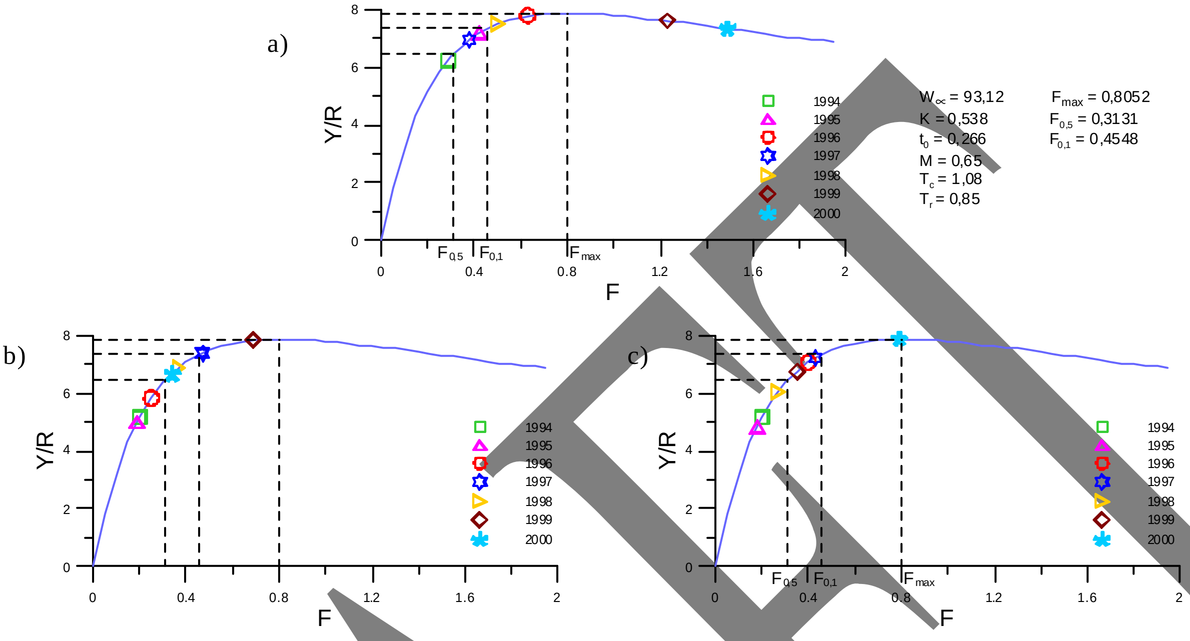

1.6
1.2
0.8
0.4
0
1994
1995
1996
1997
1998
1999
2000
Zone 1 - SE
Zone 7 - S
Zone 6 - SW

Fig. 5



a)
Y/R
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F0,1
Fmax
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1.2
1.6
2
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1994
1995
1996
1997
1998
1999
2000
W∞ = 93,12
K = 0,538
t0 = 0,266
M = 0,65
Tc = 1,08
Tr = 0,85
Fmax = 0,8052
F0,5 = 0,3131
F0,1 = 0,4548
b)
Y/R
8
6
4
2
0
0
0.4
0.8
1.2
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c)
Y/R
8
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F0,5
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F
1994
1995
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1998
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Fig. 6

Fig. 1 – Study area.

Fig. 2 – Percentage increase of TGT during the years 1991-2000; a) for Zone 1 (South-Eastern); b) for Zone 7 (Southern); c) for Zone 6 (South-Western).

Fig. 3 –Index trends from 1994 to 2003. Biomass index (kg/km^2) for Zone 1 (a), 7 (b) and 6 (c); Abundance index (n/km^2) for Zone 1 (d), 7 (e) and 6 (f).

Tab. 1 – Two-way ANOVA. Summary table of Aristaeomorpha foliacea biomass indexes, indicating the sources of variance.

Tab. 2 – Two-way ANOVA. Summary table of Aristaeomorpha foliacea log-transformed abundance indexes, indicating the sources of variance.

Fig. 4 – Trend of Fishing mortality rate (F) for each cohort; a) Zone 1; b) Zone 7; c) Zone 6.

Fig. 5– Trend of average F, from 1994 to 2003, for each Zone

Fig. 6 – Fishing mortality rate compared to the reference points F_{max}, $F_{0.1}$ and $F_{0.5}$ for: a) Zone 1; b) Zone 7; c) Zone 6;

USE OF AN EXPLOITATION RATE THRESHOLD IN THE MANAGEMENT OF ANCHOVY AND SARDINE STOCKS IN THE ADRIATIC SEA

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Abstract

The use of a biological reference point based on exploitation rate threshold was evaluated for the stocks of anchovy and sardine in the central and northern Adriatic Sea. This threshold was suggested for small pelagics by K. Patterson in 1992. The values of the fishing mortality rates F in the exploitation rates F/(M+F), with M being the rate of natural mortality, were derived from VPA carried out for the time interval 1975-2001. The results were encouraging so that this threshold could be used to prevent stock collapse along with the Minimum Biological Acceptable Level (MBAL) based on spawning stock biomass, currently implemented for small pelagic fish and other species. The same exploitation rate threshold could even substitute MBAL, when not sufficiently long time series of stock-recruitment data are available to obtain reliable estimates of MBAL.

Key words: Adriatic Sea, *Engraulis encrasicolus*, exploitation rate, *Sardina pilchardus*, population dynamics, reference points, stock assessment, VPA.

Introduction

Anchovy (*Engraulis encrasicolus*, L.) and sardine (*Sardina pilchardus*, Walb.) are among the most important commercial species both in the Mediterranean and Adriatic Sea. Since 1975, the ISMAR Marine Fisheries Section of Ancona has been conducting research on the biology and stock assessment of both species in the central and northern Adriatic, by means of population dynamics methods (Cingolani *et al.*, 1996, 1998, 2000; 2002a,b; Santojanni *et al.*, 2001, 2002, 2003).

In the management perspective of these stocks, as for other exploited species, the choice of appropriate biological reference points is a matter to be attended. These indicators are utilized to avoid too much high fishing mortality and, thus, depletion of resources (Haddon, 2001; Hilborn and Walters, 1992; Murawski *et al.*, 2001; Myers *et al.*, 1994; Patterson, 1992; STECF, 2002). In the present paper, the use of a critical threshold for the exploitation rate is discussed. This application is relative to recent assessments of anchovy and sardine stocks in the ambit of a project funded by Ministero Italiano per le Politiche Agricole e Forestali (Cingolani *et al.*, 2002b). These assessment were carried out by means of Virtual Population Analysis (VPA) on the two corresponding time series from 1975 to 2001 (the data collection for subsequent years is still ongoing).

The exploitation rate is given by the ratio between the two instantaneous rates of fishing mortality, F, and total mortality, Z, which is equal to F+M, with M being the natural mortality rate. In the present work, both F and M are always meant on annual basis. The critical threshold for F/Z was taken to be equal 0.4. Such a value was suggested by Patterson (1992) as a possible biological reference point for the management of small pelagics. In order to find it, Patterson used data derived from many literature sources, represented from values of biomass and corresponding fishing mortality rates estimated by VPA, along with the same M values employed by VPA, in assessments of 28 stocks distributed in all the world and relative to 11 species of small pelagics: *Sardina pilchardus, Sprattus sprattus, Clupea harengus*, etc. The ratio F/Z was used instead of F because the former one allows to obtain more comparable indices, which account for different natural mortality in different species and even stocks of the same species. The rates of variation of biomass, plotted as a function of F/Z, were calculated by the author using time intervals ranging from 5 to 10 years. In the case of those stocks with long historical series, more than one time interval was used, so that the data points fitted by means of regression techniques were 53, thus quite over 28, *i.e.* the number of examined stocks. The statistical analysis performed by Patterson suggested that, over the value F/Z = 0.4, stocks show high probabilities of decline. Such probabilities become particularly high over F/Z = 0.5, which is obtained when F = M : this outcome is consistent with the conclusions derived by other authors on the basis of different methods (Patterson, 1992). On the contrary, a value of F/Z under 0.3 seems to be compatible with increasing stock abundance and associated to a relatively low risk of decline.

Finally, in the same work, Patterson remembered the disadvantages shown by different biological reference points applied in the management of small pelagic stocks. In particular, he emphasized that the Minimum Biological Acceptable Level (MBAL), currently implemented (STECF, 2002), requires long time series relative to the abundance of both spawners and recruits. In fact, only long series allow to “capture” the threshold of spawning stock biomass to be maintained at sea, under which, otherwise, a strong decline is likely to occur.

Material and methods

Three kinds of data were collected, related to catch, fishing effort, biometric features.

Landing data were collected on census basis for both west (Italy) and east (Slovenia, Croatia, ex Yugoslavia) Adriatic ports (Cingolani *et al.*, 1996; Santojanni *et al.*, 2003). The distribution of the sampled ports has Vieste as southern limit (Fig. 1), so that the whole GSA 17 of GFCM is investigated. Anchovy landings can be considered a reliable estimate of catches because the Adriatic anchovy is mainly fished by the Italian fleet and, in this country, is always required by the market so that discarding is thought to be negligible (Cingolani *et al.*, 1996, 2000). For sardine, a more relevant practice of discarding at sea likely occurred in some Italian ports since the end of the 1980s onwards, so estimates - ranging from around 900 to 4 000 tonnes per year - were obtained (Cingolani *et al.*, 2000; 2002a).

All these landings are relative to mid-water trawlers (in Italy *volanti*) and purse-seiners (in Italy *lampare*) using fish attraction by light (Cingolani *et al.*, 1996), which usually target schools formed by individuals larger than about 9 cm in length.

Biological samples were collected in the most important Italian ports on the basis of landed catches, in order to obtain length, weight, age data of both species. Age of fish was estimated by reading otoliths. The use of calendar year data in fishery stock assessments implies that the conventional birthday (*i.e.* the day on which a cohort grows one year older) is on the first day of January. This is the case of Adriatic sardine but not of anchovy. Since the reproduction of the Adriatic anchovy is particularly relevant in spring-summer (Regner, 1996), a conventional birthday on the first of June is more sensible: the assessment for this species was thus carried taking into account such a birthday date. The birthday effect is expected to be not negligible more likely in assessments based on catch-at-age data, just like VPA. Consequently, all data originally recorded according to calendar year were then modified in order to calculate split year ones, so that data relative to one year 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 (Santojanni *et al.*, 2003).

The VPA is a method used for many species, including small pelagics. Some examples from literature, relative just to small pelagics, can be found for stocks distributed in all the world (Barange, 2001; Patterson, 1992; Schwartzlose *et al.*, 1999). The VPA yields estimates of the stock abundance at sea on the basis of catch-at-age data over time and, to do that, it assumes the instantaneous natural mortality rate to be constant over time and age classes (Haddon, 2001; Hilborn and Walters, 1992). The values $M = 0.6\ yr^{-1}$ and $M = 0.5\ yr^{-1}$ were used for anchovy and sardine, respectively, taking into account both the age composition of catches and estimates reported in literature (Cingolani *et al.*, 2002b; Santojanni *et al.*, 2003). In particular, the value M = 0.5 was obtained for Adriatic sardine by Sinovcic (1986). It is also of some interest to remember that values of M ranging from 0.29 to 0.62 were obtained for a well studied sardine stock (Catalan Sea) in the Mediterranean (Pertierra and Perrotta, 1993).

Table 1 and Table 2 show examples of age-length key for anchovy and sardine, respectively. It should be noted for sardine that individuals older than 6 up to 12 years are recorded, suggesting relatively high longevity and, hence, probably not so much high natural mortality. In other words, that can justify the use of M = 0.5, because higher values of M could not allow to explain the occurrence of the old individuals mentioned. Further, this is derived from catches: likely, without the fishing pressure (*i.e.* Z given by M only), these older individuals would be better represented in the population at sea and, thus, more frequently encountered in sampling.

The longevity suggested for anchovy by the age-length key is lower than for sardine, with the oldest individuals being in the age class 6. The age classes 5 and 6 resulted to be in other annual age-length keys, except for the years immediately after the collapse of the stock (Santojanni *et al.*, 2003; see also below). Anyway, the value 0.6 is near the lowest end limit of the interval of values reported in literature and, here, was taken also according to precautionary approach (Santojanni *et al.*, 2003). Therefore, VPA was also performed using M = 0.8 and accounts about results are reported below when the disadvantages of the critical threshold of F/Z are discussed. Again, a reference to the well studied case of Catalan Sea is worth: for the anchovy stock, Pertierra and Lleonart (1996) mentioned M = 0.54 and M = 0.81, which are very similar to the values employed here for Adriatic anchovy. Finally, the criterion to select M on the basis of the inverse relationship with longevity is adopted for small pelagics by other authors; as reported in a recent GLOBEC report (Barange, 2001), Pacific sardine (*Sardinops sagax*) is usually assumed to have a relatively low annual natural mortality rate, M = 0.4, and a lifespan of about 10 years, whereas for northern anchovy (*Engraulis mordax*) M = 0.8 is associated to a lifespan of about 4 years.

The VPA allows to calculate annual values of stock abundance at sea and fishing mortality rates by age and year. The rates relative to the oldest age groups and most recent (final) year were calculated using the procedure defined by Cingolani *et al.* (2002b) and Santojanni *et al.* (2003); this, in particular, involved Laurec-Shepherd tuning on CPUE-at-age data obtained for Porto Garibaldi (Santojanni *et al.*, 2002), whose fleet accounts over years for 20-25% of catches of anchovy as well as sardine. The software package employed for the VPA runs was MAFF-VPA, developed by Darby and Flatman (1994).

The annual exploitation rates, F/Z, were calculated using the same values of M utilized by VPA and the annual values of F_{0-3} and F_{0-5} for anchovy and sardine, respectively. These values of F are the averages of the F-at-age values yielded by VPA for the age intervals 0-3 and 0-5. They were calculated as arithmetic unweighted means or FBAR (Darby and Flatman, 1994). As stressed by Patterson (1992), the same F values, weighted on the basis of the abundance at sea by age class, would have been preferable. However, Patterson performed statistical analysis on a data set mainly formed by unweighted averages. Hence, the threshold and/or grid for F/Z pointed by this analysis have to be thought like an “instrument tuned” on unweighted averages. In fact, unweighted averages are expected to be higher than weighted ones: in the latter case, the arithmetic weight of younger age classes increases because of the higher abundance, and lower values of F are usually estimated for these classes. Anyway, short accounts about the use of so weighted mean F values were reported.

Results and discussion

The annual values, on split year basis, of mid-year total biomass at sea of the anchovy stock are shown in Figure 2, along with the corresponding biomass of spawners and annual total catches. These represent, on the average, the 24% of mid-year total biomass. The trends of biomass at sea show higher values in the second half of the 1970s and, then, a decline till 1987, when the minimum level of the series is observed. In consequence of that, in the calendar 1987, a strong crisis of this fishery occurred in the Adriatic, as pointed by the fall of catches in the same figure. After the collapse, a partial recovery of both abundance and catches is observed. The increase in 2001 is likely an overestimate yielded by VPA, due the fact that catch-at-age data processed by VPA cannot account for the complete history of the most recent cohorts.

In Figure 3, the annual values of total biomass estimated by VPA are compared with the corresponding series of biomass density obtained from echo-surveys approximately in the same Adriatic area (Azzali *et al*., 2002a). The two trends are not very different so that our assessment is corroborated. Both methods perceive the peak in the second half of the 1970s, strong decline and partial recovery. The contrast between the first period mentioned and the end of the 1980s resulted to be also in the assessment based on ichtyoplanktonic method carried out by Regner (1996), as shown by Santojanni *et al*., (2003). Coming back to acoustics, the low level of abundance in 1976 strongly increased in the subsequent year and the decrease at the beginning of the 1990s are not seen by VPA: it is difficult to understand if these fluctuations obtained from the echo-surveys are due to changes in the natural mortality, not taken into account by VPA, or to different sources of error for both methods. The series shown here for acoustics is updated to 1998: data from 1999 to 2001, shown by Azzali *et al*. (2002b) in an unpublished report, are still consistent with the VPA trend.

The Figure 4 shows the estimated annual values of F_{0-3} obtained for anchovy: they increase progressively since 1976 and a quite high value is observed just in 1986, $F_{0-3} = 0.67$. Likely, a high fishing pressure could have contributed to the collapse. However, the levels of recruitment in 1986 and 1987 were particularly low in relation to the spawning biomass of the previous years 1985 and 1986: similar levels of spawners yielded higher levels of recruits in other years, *e.g.* 1995 (see below). This suggests that different factors, environmental ones and/or interactions with other species, could have contributed to the collapse (Cingolani *et al.*, 2002b; Santojanni *et al.*, 2003). The importance of multiple factors in determining the population dynamics of small pelagics - such as other species - is widely discussed in literature (Barange, 2001; Beverton, 1990; Hilborn and Walters, 1992; Lasker, 1985; Schwartzlose *et al.*, 1999; Smith, 1983).

The annual values of the anchovy exploitation rate F/Z are shown in Figure 5, along with the corresponding average for the whole period 1976-2001. This is estimated to be equal to 0.34, which is under the threshold 0.4. However, some annual values are close (in 1984 and 1985) or higher (in 1982, 1983, 1986) than the value 0.4. In 1986, F/Z is even higher than the "very dangerous" limit 0.5; like for fishing mortality rates, this occurs just immediately before the collapse. As said in Introduction, the analysis performed by Patterson (1992) was based on variations of stock biomass within periods between 5 and 10 years. That is not necessarily to the detriment of the hypothesized negative influence on the Adriatic anchovy due to fishing pressure in those few years. In fact, as stressed by the same author, a high level of exploitation, even if occurring within a shorter time interval, can contribute to the decline of stocks. In the present case, warning should be derived in at least three years before collapse. After this event, instead, the values are always lower than 0.4: that is consistent with the contemporaneous stock recovery. Finally, the exploitation rates calculated using weighted values of F_{0-3} showed an average, on the whole period, equal to 0.24, against 0.34 obtained when using the unweighted values of F_{0-3} . In the former case, the values decreased because of the increased weight of the younger age classes which displayed lower rates of fishing mortality. Anyway, the estimate of F/Z obtained for 1986 remained essentially unchanged: 0.51 against 0.53 obtained without weighting. In conclusion, the weighting procedure increased the difference between F/Z in 1986 - as well as in 1982 with 0.39 against 0.44 - and F/Z in all the other years.

The annual values of mid-year total biomass at sea of the sardine stock are shown in Figure 6, along with the corresponding biomass of spawners and annual total catches. These represent, on the average, the 14% of mid-year total biomass. The trends of biomass at sea increase since 1975 up to 1984, then a quasi continuous decline is observed till 2000, in correspondence with the lowest abundance levels of the series. The increase shown by the total biomass in 2001 - not sustained by an increased spawning biomass as well - is likely an overestimate yielded by VPA due the same reasons mentioned for anchovy.

The comparison between abundance trends from VPA and the echo-surveys carried out by Azzali *et al.* (2002a), shown above for anchovy, was also done for sardine (Fig. 7). Analogous considerations hold: an overall agreement is observed but the increase at the beginning of the 1980s and the decrease in the middle of the same decade are clearly smoothed in the VPA trend. It is worth mentioning that the biomass density in the series updated to 2001, reported by Azzali *et al.* (2002b), is still declining just like in the VPA estimates.

The Figure 8 shows the estimated annual values of F_{0-5} obtained for sardine. It is evident that the relatively high values observed for anchovy in some years are not recorded for sardine.

The annual values of the sardine exploitation rate F/Z are shown in Figure 9, along with the corresponding average for the whole period 1975-2001. This is estimated to be equal to 0.36, again under the threshold 0.4 as in the case of anchovy. Some annual values of F/Z higher than 0.4 are also observed for sardine as, for example, in the period 1981-1984 and, after the mentioned quasi continuous decline of the stock, in 2000-2001. Such a decline begins just in the middle of the 1980s. However, it is so pronounced and long over time to be unlikely attributable only to few values of F/Z slightly higher than the threshold 0.4. In fact, the level of estimated biomass is high in comparison with the catches both before and after the decline, with the exception of the most recent years. Likely, as (if not more than) in the case of anchovy, other factors than fishery influenced the population dynamic of sardine in this period. Anyway, it should not be ignored that, in 1981-1984, the catches were particularly high (around 80 000 and 90 000 tonnes) and relatively not far from the level of spawning biomass, *i.e.* around 40%. This accounts for a high value of F in the higher age classes and, thus, of unweighted F/Z in these years. The warning, on the contrary, seems to be more reliable for the year 2000 and, even if with more caution as it is the final year in the VPA run, for 2001; the overcoming of the threshold is here associated to the lowest estimated biomass, observed after a long time decline, which also results to be in the echo-survey assessment. Moreover, some difficulties in obtaining economically satisfactory catches by fishermen were perceived since the spring of 2001 up to current months of the beginning of 2004. That occurred particularly in Croatia (G. Sinovcic, pers. comm.), where sardine is more requested by the market than in Italy, but also in some Italian ports such as Chioggia and Cesenatico, whose fleets fish sardine by contracts with canning factories. Furthermore, the exploitation rates calculated using weighted values of F_{0-5} showed an average, on the whole period, equal to 0.18, against 0.36 obtained when using the unweighted values of F_{0-5} . The highest values in the series obtained by weighting ranged from 0.24 to 0.29 and corresponded to the period 1997-2000: that further stresses a more reliable warning for the most recent years than the first half of the 1980s.

The use of F/Z as a biological reference point has a disadvantage: it requires a value of M, a parameter difficult to estimate (Haddon, 2001; Hilborn and Walters, 1992). The higher the value of M the lower the exploitation rate. However, the changes of M do not necessarily imply drastically different scenarios for this potential reference point. For example, in the case of anchovy stock, also according to precautionary approach, M = 0.6 was used. When the VPA calculations were repeated with the alternative value M = 0.8, the exploitation rates resulted to be equal to 0.41 in 1986 and ranging from 0.3 to 0.4 in the four years before. Therefore, F/Z values around the critical threshold 0.4 were obtained, suggesting again, even if in a less strong way, a situation of risk.

The reason that could make the critical threshold of F/Z preferable to a critical value of spawning biomass at sea, is due to the fact that it is not always possible to work on enough long time series to estimate the threshold under which collapse is probable. An example of empirical stock-recruitment relationship, obtained for the Adriatic anchovy on the basis of the same VPA run which yielded F/Z, is reported in Figure 10 (the analogous graphic for sardine is shown in Figure 11). Here, the number of recruits in the year n+1 is plotted as a function of the spawning biomass in the previous year n. The abundance of spawners in the period 1985-1986, associated to particularly low recruitment in 1986-1987, shows values lower than 60 000 tonnes. It is not a case that a value of Minimum Biological Acceptable Level (MBAL) equal to 60 000 tonnes was pointed for this stock in a previous assessment discussed in a scientific report to the Commission of European Communities (Cingolani *et al.*, 1998). To be close or under this critical threshold does not necessarily imply collapse: the spawning biomass relative to the year 1994 was similar to that recorded in 1985, but yielded a quite higher number of recruits in 1995. Anyway, on the basis of this kind of plot and the experienced crisis really occurred, this threshold was thought to be a warning of risk. A value of MBAL around 60 000 tonnes was also obtained independently of the knowledge gained from the experienced crisis. Such a value was the estimated spawning biomass associated to the half of theoretical maximum recruitment level, which was derived by fitting the Beverton-Holt model to the empirical distribution (Myers *et al*., 1994). Now, an interesting exercise should be done, looking at Figure 10 excluding the data points in the down left-hand corner, or in the top right-hand corner as well: without the experienced collapse, in order to estimate MBAL, methods like that based on the half of theoretical maximum recruitment should be applied. That would yield different estimates of MBAL in comparison with all the data points being used. In the former case, the threshold of spawning biomass would be too much or too little conservative than the latter one. Independently from collapse occurred, plots with missing information are expected in situations with relatively short time series. It is easy to understand the usefulness of F/Z in such situations, as it does not require long time series.

Conclusions

On the whole, the results of the analysis of exploitation rates F/Z seemed to be consistent with the conclusions derived by Patterson (1992). The use of the critical threshold F/Z = 0.4 in the management of anchovy and sardine stocks is therefore encouraged. Two other potential reference values are 0.3 and 0.5, so that a grid of values of F/Z could also be employed. This type of biological reference point could be added to the estimated spawning stock biomass to be maintained at sea. In particular, it could even substitute MBAL when not sufficiently long time series of stock-recruitment data are available to obtain reliable estimates of MBAL.

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Table 1 - Anchovy: age (year) - length (cm) key calculated for the year 1995. Proportions represent age frequency distributions by length class.

Length	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
9	0	0	0	0	0	0	0
9.5	0.98	0.02	0	0	0	0	0
10	0.86	0.14	0	0	0	0	0
10.5	0.92	0.08	0	0	0	0	0
11	0.75	0.25	0	0	0	0	0
11.5	0.50	0.50	0	0	0	0	0
12	0.26	0.74	0	0	0	0	0
12.5	0.16	0.83	0.01	0	0	0	0
13	0.06	0.81	0.14	0	0	0	0
13.5	0.01	0.45	0.52	0.02	0	0	0
14	0	0.17	0.45	0.37	0.02	0	0
14.5	0	0.11	0.22	0.57	0.11	0	0
15	0	0.02	0.16	0.36	0.40	0.07	0
15.5	0	0.01	0.21	0.24	0.39	0.14	0.01
16	0	0	0.07	0.30	0.29	0.28	0.06
16.5	0	0	0.06	0.23	0.19	0.32	0.19
17	0	0	0	0.42	0.19	0.15	0.23
17.5	0	0	0	0.33	0.50	0.17	0
18	0	0	0	0.67	0.33	0	0
18.5	0	0	0	0	0	0	0

Table 2 - Sardine: age (year) - length (cm) key calculated for the year 1998. Proportions represent age frequency distributions by length class.

Length	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12
13	1	0	0	0	0	0	0	0	0	0	0	0	0
13.5	0.72	0.28	0	0	0	0	0	0	0	0	0	0	0
14	0.33	0.67	0	0	0	0	0	0	0	0	0	0	0
14.5	0.26	0.69	0.05	0	0	0	0	0	0	0	0	0	0
15	0.08	0.64	0.25	0.03	0	0	0	0	0	0	0	0	0
15.5	0.02	0.38	0.53	0.07	0	0	0	0	0	0	0	0	0
16	0	0.03	0.56	0.39	0.02	0	0	0	0	0	0	0	0
16.5	0	0.01	0.31	0.49	0.17	0.02	0	0	0	0	0	0	0
17	0	0	0.06	0.42	0.42	0.09	0	0.01	0	0	0	0	0
17.5	0	0	0	0.15	0.47	0.30	0.06	0.01	0	0	0.01	0	0
18	0	0	0	0.03	0.29	0.54	0.12	0.02	0	0	0	0	0
18.5	0	0	0	0	0.07	0.38	0.35	0.14	0.03	0.02	0.01	0	0
19	0	0	0	0	0	0.04	0.39	0.37	0.14	0.04	0.02	0	0
19.5	0	0	0	0	0	0	0	0.50	0.15	0.15	0.15	0.05	0
20	0	0	0	0	0	0	0	0	0.25	0.50	0	0	0.25
20.5	0	0	0	0	0	0	0	1	0	0	0	0	0

Figure legends

Fig. 1 - Geographic extent of the small pelagic data collection: the port of Vieste represents the southern limit (see text).

Fig. 2 - Anchovy: total annual catch, total biomass and spawning biomass calculated in the middle of the year by VPA, from 1976 to 2001(split year data, see text).

Fig. 3 - Anchovy: mid-year total biomass estimated by split year (see text) VPA and biomass density derived from echo-surveys, are compared over years.

Fig. 4 - Anchovy: fishing mortality rate, F, for the age class interval 0-3, estimated by VPA from 1976 to 2001 (split year data, see text). The average for the whole period is also reported.

Fig. 5 - Anchovy: exploitation rate, F/(F+M), from 1976 to 2001 (split year data, see text). The average for the whole period is reported along with the threshold, 0.4, suggested by Patterson (1992).

Fig. 6 - Sardine: total annual catch, total biomass and spawning biomass calculated in the middle of the year by VPA, from 1975 to 2001.

Fig. 7 - Sardine: mid-year total biomass estimated by VPA and biomass density derived from echo-surveys, are compared over years.

Fig. 8 - Sardine: fishing mortality rate, F, for the age class interval 0-5, estimated by VPA from 1975 to 2001. The average for the whole period is also reported.

Fig. 9 - Sardine: exploitation rate, F/(F+M), from 1975 to 2001. The average for the whole period is reported along with the threshold, 0.4, suggested by Patterson (1992).

Fig. 10 - Anchovy: empirical relationship between the abundance at sea of spawners in the year n and recruits in the year n+1 (the latter being reported near the data points), on the basis of split year (see text) VPA estimates.

Fig. 11 - Sardine: empirical relationship between the abundance at sea of spawners in the year n and recruits in the year n+1 (the latter being reported near the data points), on the basis of VPA estimates.

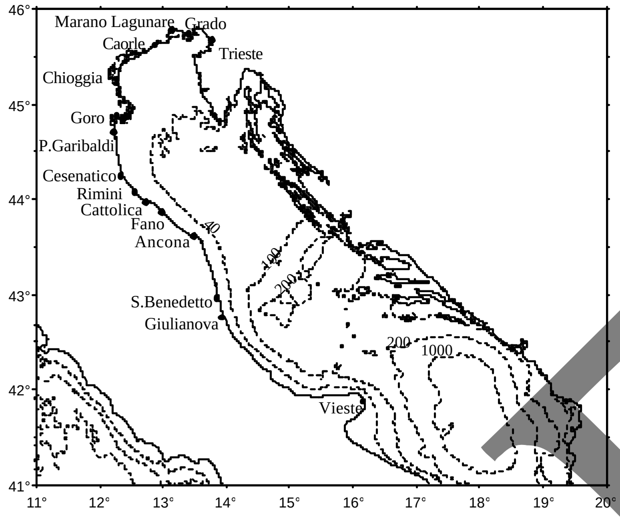


Fig. 1

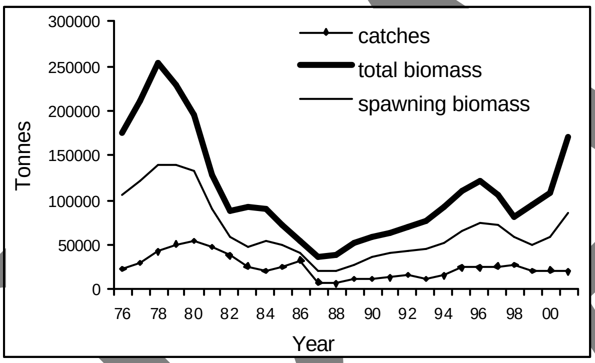


Fig. 2

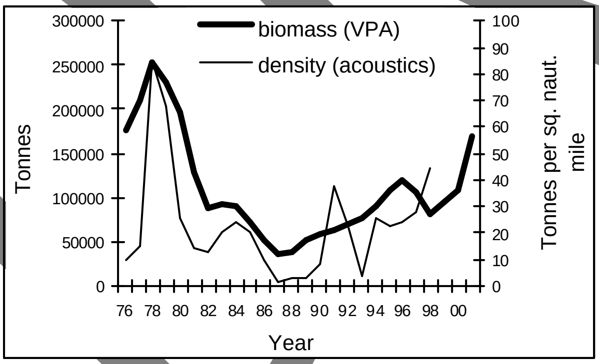


Fig. 3

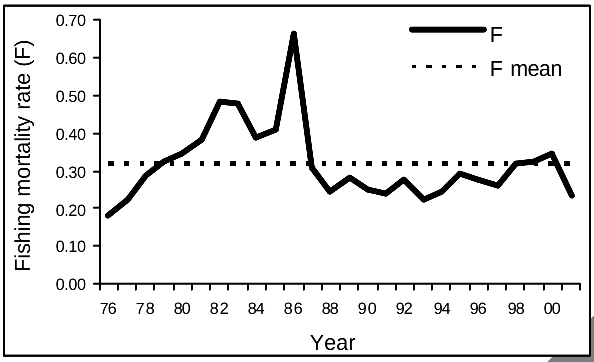


Fig. 4

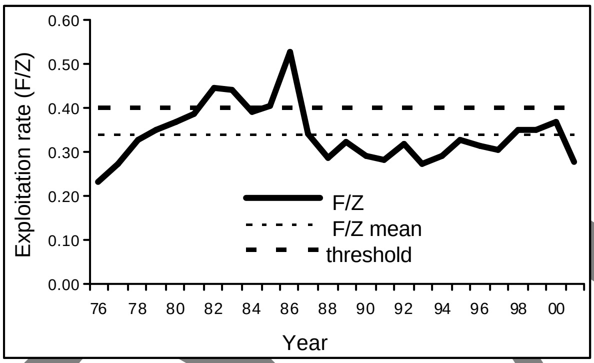


Fig. 5

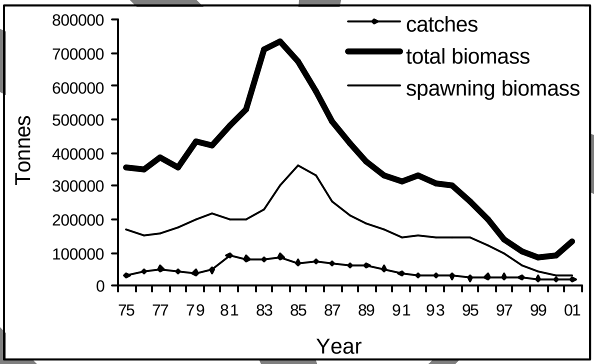


Fig. 6

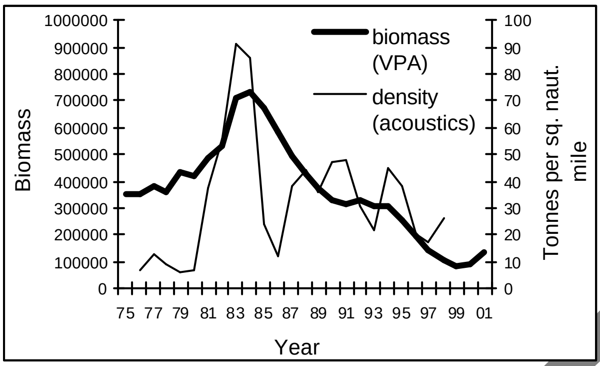


Fig. 7

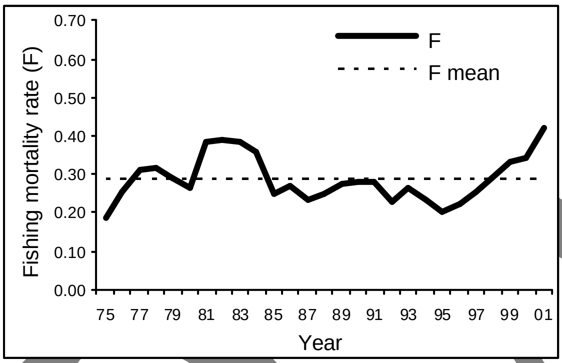


Fig. 8

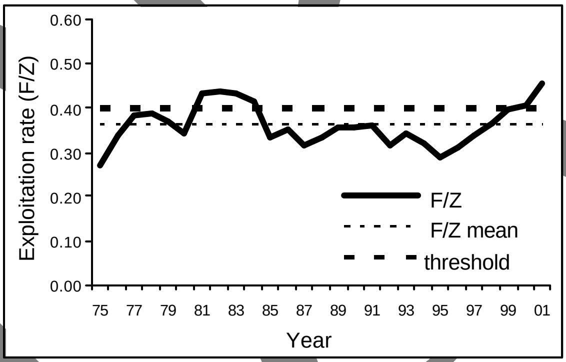
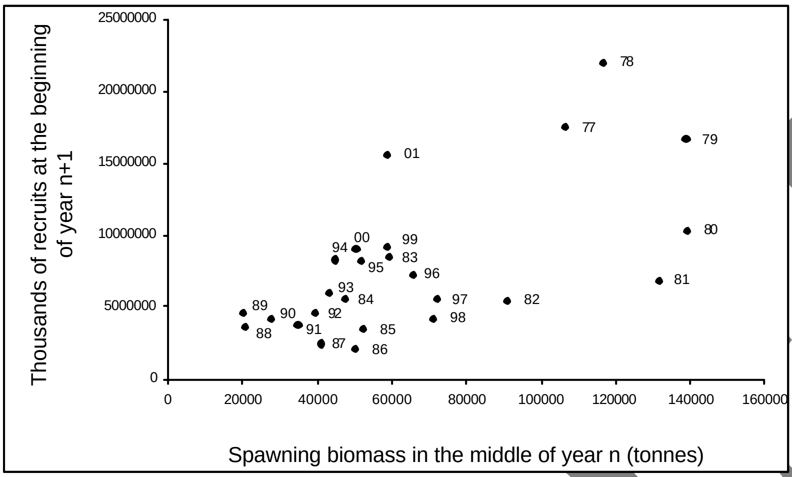


Fig. 9


Thousands of recruits at the beginning of year n+1
25000000
20000000
15000000
10000000
5000000
0
0
20000
40000
60000
80000
100000
120000
140000
160000
Spawning biomass in the middle of year n (tonnes)
78
77
79
01
80
00
99
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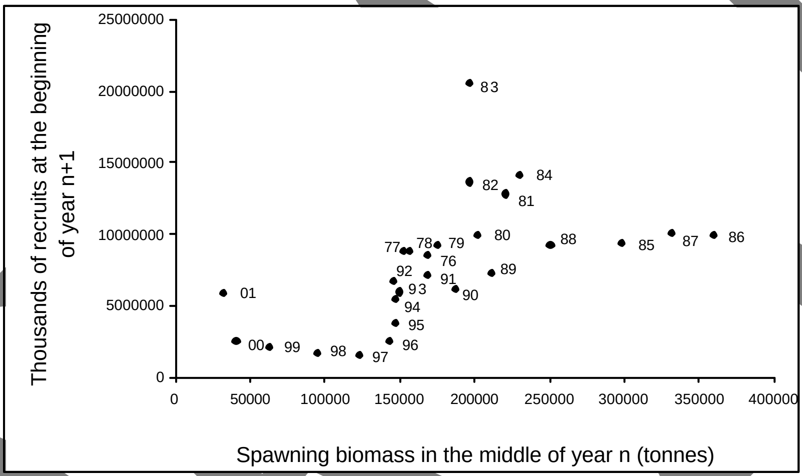
86

Fig. 10


Thousands of recruits at the beginning of year n+1
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Spawning biomass in the middle of year n (tonnes)
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Fig. 11

Biological reference points based on spawning stock biomass levels: the case of the red mullet (*Mullus barbatus* L., 1758)

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Abstract

Biological reference points often reflect the combination of several components of stock dynamics (growth, recruitment and mortality) into a single index. Recently, also interactions among different fish stocks as well as cross-relationships between these and the surrounding marine environment represent a relevant challenge (i.e. ecosystem based approach to fishery management). In addition, the BRPs identify target and threshold levels to consider for a sustainable fishery (Precautionary BRP).

Facing the problem of identification of suitable BRPs, two main aspects are often addressed in Mediterranean, i.e. testing the potential of indicators used in other geographical regions (e.g. ICES context) and evaluating BRPs that better incorporate the biological/technical specific characteristics of the area.

The objective of this paper is to test BRPs based on the spawning stock biomass (SSB), using as case study the stock of red mullet of the central-southern Tyrrhenian Sea (GSA 10). Data (abundance indices and demographic structure of the population) are from the bottom trawl surveys GRUND and MEDITS carried out since 1994.

Growth and mortality, with associated variability, were estimated following the temporal evolution of the different cohorts, which were separated using a maximum likelihood estimator. Maturity and size at first capture were estimated as well, the latter from selectivity experiments conducted in the area. All these estimates (parameters and vectors by size) were the input of a stochastic simulation model (biomass pool dynamic model) based on the Thompson & Bell approach. The condition of *M. barbatus* stock was thus modelled accounting for fluctuations in the growth parameters, recruitment and maturity. Safe levels occurred when the ratios SSB/SSBV and SSB/B were respectively higher than 20 (~25) and 50%, corresponding to B/R of 80 g and to an exploitation rate of ~0.55. Critical size should thus be higher than 121 mm that is ~90% of the $Lm_{50\%}$. Suitable management options could be represented by the enforcement of the area and temporal closure.

Key words: biological reference points, spawning stock biomass, *Mullus barbatus*, Tyrrhenian Sea, trawl survey.

Introduction

Biological reference points (BRPs) often reflect the combination of several components of stock dynamics (growth, recruitment and mortality) into a single index.

In geographical regions (e.g. Atlantic Ocean, North Pacific, North Sea) where fisheries are managed following an adaptive strategy since long time, the identification of pertinent BRPs relies on the stock assessment models currently used to provide estimates of population abundance and to shed light on the underlying dynamics. Depending on the assessment and management techniques, BRPs can be expressed in

terms of fishing mortality rate *F*, stock biomass *B*, spawning-stock biomass *SSB*, or other metrics of exploitation rate or stock abundance (e.g. Smith *et al.*, 1993; Restrepo *et al.*, 1999). In the frame of the precautionary approach (e.g. FAO, 1995; FAO, 1999) the need to distinguish between Target and Limit Reference Points has been well established identifying threshold levels for a sustainable fishery (e.g. Smith *et al.*, 1993; Mace, 1994; Caddy and Mahon 1995; Prager *et al.*, 2003).
Recently, also interactions among different fish stocks as well as cross-relationships between these and the surrounding marine environment represent a relevant challenge (i.e. ecosystem based approach to fishery management). This is, however, a very complex task as we need to understand the ecosystem well enough to predict with reasonable confidence the consequences of fishing removals on different stocks. Also we need to consider competition between species (for food and habitat) and interactions between juvenile fish as well as predation by adults. In all of these aspects much work has been done (e.g. Pope, 1991; Sparre, 1991; Christensen and Pauly 1992; AA.VV., 2000; Walters et al., 2000; Rochet and Trenkel, 2003), but further work is still required in understanding marine ecosystems and incorporating complex ecological/production assessments into quantitative management advice.
Considering the high degree of uncertainty inherent in fisheries research and the complexity of the whole system (e.g. Hilborn and Walters, 1992; Walters, 1998) holistic approaches accounting for stock dynamics, ecological, social and economic implications (e.g. Caddy, 1999; 2002; Garcia *et al.*, 1999; Pitcher, 1999) are recognised to be more robust and integrated techniques for a multidisciplinary evaluation of the fisheries sustainability.
Whatever is the method selected to provide management advice, diagnostics of the main stocks targeted is still relevant, at least as part of a more complex evaluation frame.
In Mediterranean, where the identification and adoption of BRPs is currently recommended by scientific and management Bodies (i.e. GFCM and European Commission), two main aspects are still faced: testing the potential of indicators used in other geographical regions (e.g. ICES context) and evaluating BRPs that better incorporate the biological/technical specific characteristics of the area. This is a difficult task because, given the complexity and diversity of Mediterranean fisheries, the available data are probably not sufficient for regularly and trustworthy assessment for most species (Lleonart and Maynou, 2003).

The objective of this paper is to investigate on the dynamics of the red mullet stock in the central-southern Tyrrhenian Sea (geographical sub-area – GSA 10), assessing the level of reproductive capacity and its capability to maintain sustainable productivity, i.e. if year-classes produce sufficient spawning units so that successive generations replace, on average, each other. Hence BRPs based on the spawning stock biomass (SSB) have been tested.
The red mullet was selected as case-study given its economic importance and wide distribution along the Mediterranean coasts (e.g. Tserpes *et al.*, 2002). In Italy, for example, the production of red mullet in 2002 was14,310 tons, accounting for 10.2% of fish production excluding pelagic stocks (IREPA, 2003).
In addition, the specific features of the life history traits (discrete recruitment mode, early maturation) and of the fishing patterns (target species of the trawlers) make this species a suitable subject to test BRPs.

Material and Methods

The data used in this paper (abundance indices and length structure of the red mullet population) are mainly from the bottom trawl surveys GRU.N.D. (Relini, 2000) integrated with those from MEDITS (Bertrand et al., 2003). Both surveys were carried out along the Italian coats since 1994, respectively in autumn (September-October) and spring (May-June). Thus time series from 1994 to 2002 were employed in this analysis. Further details on the stratification scheme (stratified random sampling, each haul position randomly selected in small sub-areas) and sample allocation (proportional to the depth stratum areas) are in the aforementioned papers as well as in Greco *et al.*, 1998 and Spedicato *et al.*, 1998 with specific reference to the geographical sub-area (10-Central-Southern Tyrrhenian Sea). The total explored surface (from 10 to 800 m depth) was 20255 km^2, while the continental shelf, where the red mullet is preferentially distributed, is extended for 7362 km^2. Density in number and length frequency distributions were thus weighted accounting for this area and standardised to the square kilometre.

Given the discrete recruitment mode of the species and the timing of the surveys, the data on both recruits (from GRU.N.D. survey) and adults (from MEDITS survey) were available.

Growth and total mortality, with associated variability (calculated for the curvature parameter K and the total mortality Z, whereas approximated, i.e. ±5%, for the asymptotic length L_8 and t_0 parameter), were estimated following the temporal evolution of the different cohorts. These were identified and separated using a maximum likelihood estimator (e.g. Fournier et al., 1990; Yamakawa and Matsumiya, 1997), according to the procedure implemented in the SAMED project (2000). For the years 1998 and 1999 parameters were estimated using only information from MEDITS, while 2002 parameters were approximated from pseudo-cohort approach.

Length at first maturity and size at first capture were estimated, the former from SAMED (2000) the latter from selectivity experiments conducted in the area (Lembo *et al.*, 2002).

All these estimates (parameters and vectors by size) were the input of a pool dynamic model built up, on the base of the forward length-based predictive Thomson & Bell approach, following the conceptual framework in Sanders (1995). Cohort's evolution followed the exponential decay model:

$$N_{t+1}=N_t\times e^{(-(M+F)(t+1-t))}$$

The input parameters and functions of the population model were: initial length; total mortality Z, from exponential decrease through time interval (full recruitment to the fishery was set at age 1); natural mortality M on the basis of empirical derivations (Beverton and Holt invariant with 1.6 coefficient); selection ogive parameters (using a stretched legal mesh size of 40 mm); length-weight relationship parameters; maturity parameters by logistic approach. In addition, recruitment indices were derived from the first component of the identified cohort projected backward according to the estimated total mortality. This index was then extrapolated to the area assumed to be occupied by the recruits). Other inputs of the model were the area occupied by population and population stage (e.g. recruits) and an empirical $\log_e$-normal distribution of recruitment with its variation chosen in the range ±20%.

In the computing procedure all the variables were treated as a vector by size. In particular the fishing mortality F was estimated as follows:

$$F(L_i) = \frac{(Z - M)}{1 + e^{\left(\frac{Ln9}{L_{75\%} - L_{25\%}}\right) * \left(L_{50\%} - Li\right)}}$$

where the natural mortality *M* was calculated according to the formulation adopted in ICES (Pope et al., 2000): *Ln*(*M*)=*Const*-0.386×3**Ln*(L_i), calibrating the constant (Pope, in SAMED) so that the derived result equals *M* of the input in the range 20%-80% of L_∞.

The model output are: Standing stock biomass (B); Spawning stock biomass (SSB); Virgin spawning stock biomass, estimated as the spawning stock biomass on which the natural mortality only was acting; average total mortality according to the Lleonart and Salat (1997) formula:

$$\overline{Z} = \frac{\sum_{ti=R}^{ti=1\%\,Ri} Z_i * \Delta_{ti}}{\sum \Delta_{ti}}$$

For each of the output variable standard deviation and coefficient of variation were computed.

Thus, in order to account for variability and uncertainty in the natural processes and estimates, the condition of *M. barbatus* stock was modelled accounting for fluctuations in the growth parameters, recruitment and maturity.

Results

Growth parameters and total mortality of the cohorts reconstructed from 1993 to 2002 are shown in Fig. 1C. The average curvature parameter *K* was from 0.30 to 0.39 (overall range: 0.236-0.447) while the asymptotic length L_∞ was from 265 to 306 mm (overall range: 252-321 mm) and t_0 from -0.2 to -0.85 (overall range from -0.19 to -0.89). The value of the natural mortality *M*, strictly correlated to *K*, was 0.48-0.63 (Fig. 1C) and the error associated in reconstructing the vector by length was from 0.03 to 0.07%. The total mortality *Z* (Fig. 1C) varied from 1.27 to 1.95 (overall range: 1.0-2.21). The exploitation rate *E* (Fig. 1C), calculated as (*Z*-*M*)/*Z* was varying from 0.52 to 0.72.

Very high fluctuations were observed in the recruitment (Fig. 1B) whose abundance was strictly correlated with the combination of two factors: the numerousness of the second modal component of the different cohorts, ranging from 139 to 1345 individuals/km^2, and the rate of total mortality acting on the cohort. The highest recruitment strength was thus observed in 2001 and the lowest in 1998 (Fig. 1B).

The size at first maturity ($Lm_{50\%}$) was set at 135 mm ($Lm_{25\%}$-$Lm_{75\%}$=30 mm) with a random variation of 5%, while the parameter of selection ogive were 89 mm ($L_{50\%}$) and 18 mm ($L_{25\%}$-$L_{75\%}$). The length-weight relationship had the following coefficients: intercept=0.000011, slope=3.025.

The model results showed that the worse combination of life history parameter (namely low *K* and *M*) and total mortality (high *Z*), as an index of exploitation, occurred for the cohort of 2001, resulting both in the lowest ratio of spawning stock biomass/virgin spawning stock biomass (SSB/SSBV=8%, Fig. 1A) and critical length (TL Cr=96 mm; Fig. 1B), estimated as the size at which the cohort reaches its maximum biomass. All the related parameters, such as the average total spawning stock biomass (600 tons, Fig. 1A), the ratio of the spawning stock biomass/biomass (SSB/B=26%; Fig. 1A), the biomass per recruit and the spawning stock biomass per recruit (B/R=52.1 g, and

SSB/R=13.5 g; Fig. 1B) were the lowest, while the average total biomass was the highest (B=2500 tons; Fig. 1A) as consequence of the cohort's recruitment strength. Conversely, the safest situation was observed for the cohort of 1998 when the lowest total mortality was acting (Z=1.27). In this case the highest ratio of SSB/SSBV (28%) and the maximum critical length (134 mm) occurred, although the total biomass was the lowest (600 tons) in coincidence with the poorest recruitment. For the other cohorts intermediate conditions were observed.

The analysis of the relationships between the different indicators of the stock state derived both by the model (SSB/SSBV, SSB/B, B/R, TL Cr) and directly from the trawl survey results (E) (Fig. 2) indicated significant correlations ($p<0.05$) among the identified BRPs and consistency in the model outputs.

The information gathered by this analysis enabled to estimate potential thresholds for the different indicators describing the condition of the red mullet stock in the studied area. Safe levels occurred when the ratios SSB/SSBV and SSB/B were respectively higher than 20 (~25) and 50%, corresponding to B/R of 80 g and to an exploitation rate of ~0.55. Critical size should thus be higher than 121 mm that is ~90% of the Lm$_{50\%}$. Conversely alarm situation could rise when SSB/SSBV and SSB/B are respectively lower than 15 and 40%, corresponding to a B/R less than 70 g and to a exploitation rate higher than 0.6. This condition would occur when critical length is less than 109 mm, i.e. ~80% of the Lm$_{50\%.}$

Discussion

The most commonly applied stock assessment method to date is the Virtual Population Analysis (VPA) by which catch at age data and estimates of natural mortality are used to reconstruct cohorts, and consequently total numbers and biomass of fish at all ages over the period for which data are available (Hilborn and Walters 1992). In Mediterranean, however the multispecific-multigear characteristics of most fisheries, the extremely dispersed landing sites, the small fraction of the catch that generally passes through organised fish markets (Lleonart and Maynou, 2003), make catch assessments in the area particularly difficult. In this situation VPA and similar techniques might provide biased estimates of the number at sea of younger ages due to undetected increases in mortality along the time, erroneous data of catches at age and of F or M estimates. Thus, most of the knowledge on the exploitation pattern of the demersal resources has been acquired by bottom trawl surveys, sampling the population at sea instead of the catches (ASA; Megrey, 1989). This approach also presents several limitations, because of possible partial coverage of the area inhabited by the stock, high variability in the estimates, timing of the survey and in turn incomplete sampling of all the population stages, availability of the different fractions of the population to the trawl net. As regards the red mullet, however, the different age classes are similarly vulnerable to the trawl. In addition, the timing of the surveys covered in our cases the occurrence of both recruits and spawners. Thus we assumed that the survey captures could be considered a proxy of the population at sea. Under this assumption, spawning stock biomass, exploitation rate and critical length were considered indicators of the fishing pressure on the stock.

Spawning-per-recruit measures are often used to estimate the impact of fishing (Parkes, 2000; Jennings et al., 2001). Ideally, a spawning-per-recruit measure would keep track of per-recruit production of larvae or eggs (Jennings *et al.*, 2001). However, spawning stock biomass per recruit (SSBR) is commonly used to estimate the reproductive output per recruit at different intensities of fishing.

Reference points that have gained prominence as proxies or independent measures of targets and limits are those based on fishing mortality at given levels of spawning stock ($F_{\%SPR}$). In particular, values in the range from $F_{20\%}$ to $F_{30\%}$ have frequently been used to characterize recruitment overfishing thresholds. The former was considered as a recruitment overfishing threshold for well-known stocks with at least average resilience, while the latter as a recruitment overfishing threshold for less well-known stocks or those believed to have low resilience (Gabriel and Mace, 1999).

Given the life history traits of the red mullet and the results from the population model, we estimated that safe levels occurred when the ratios SSB/SSBV and SSB/B were respectively higher than 20 (~25) and 50%, corresponding to B/R of 80 g and to an exploitation rate of ~0.55. Conversely alarm situation could rise when SSB/SSBV and SSB/B are respectively lower than 15 and 40%, corresponding to a B/R less than 70 g and to a exploitation rate higher than 0.6.

Our results also showed that critical size should be higher than 121 mm that is ~90% of the $Lm_{50\%}$, conversely an alarm situation would occur when critical length is less than 109 mm, i.e. ~80% of the $Lm_{50\%}$.

The analysis performed also evidenced that exploitation rate, critical size and length at maturity were suitable and simple indicators (Norris, 1991; Froese, 2004), for evaluating the state of the stock and suggesting management measures.

In Mediterranean, where an adaptive management is not implemented, the BRPs based on the spawning stock biomass should not be viewed as levels for calibrating recommended TAC (Hilborn, 2003), but more as indicators to be monitored for adjusting management measures aimed at the reduction of mortality and protection of the recruits.

Caddy (1993) after categorising three main groups of demersal species (fish with large size at first maturity captured much before the first spawning, e.g. hake, angler fish, etc.; species such as red mullet or Norway lobster that require at least a stretched mesh size of 40 mm; small species such as shrimps, cephalopods, gobies, etc., which could be completely lost increasing mesh size from 40 mm) concluded that the increasing of the mesh size, even to 60-70 mm, could be not effective in protecting the spawners of the “large fish” making, conversely, unavailable the “small species”. Thus, the effort should be reduced, and this measure should be complemented with the protection of young fish from exploitation and the protection of spawning stocks from the effects of extensive fishing.

Suitable management options for a sustainable fishery could be consequently represented by the enforcement of the areas and temporal closure.

In our analysis multispecies and multigears factors were not considered. Although the limitations inherent a single species approach, the state of the red mullet stock could be viewed as a part of a BRPs frame and as indicator of the fishing pressure exerted on the continental shelf, where this species often represents a fisheries target.

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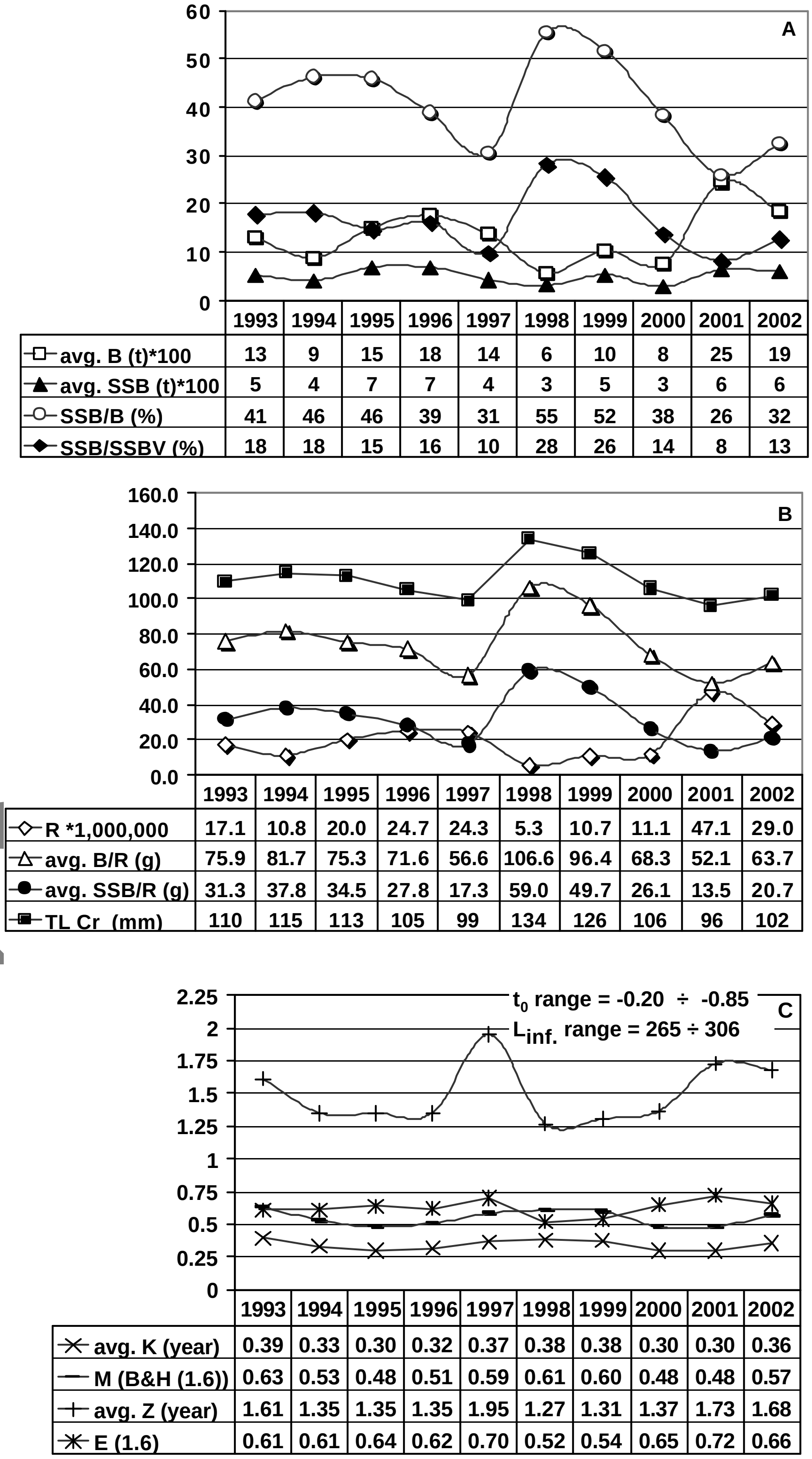

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
□ avg. B (t)*100	13	9	15	18	14	6	10	8	25	19
▲ avg. SSB (t)*100	5	4	7	7	4	3	5	3	6	6
○ SSB/B (%)	41	46	46	39	31	55	52	38	26	32
◆ SSB/SSBV (%)	18	18	15	16	10	28	26	14	8	13

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
◇ R *1,000,000	17.1	10.8	20.0	24.7	24.3	5.3	10.7	11.1	47.1	29.0
△ avg. B/R (g)	75.9	81.7	75.3	71.6	56.6	106.6	96.4	68.3	52.1	63.7
● avg. SSB/R (g)	31.3	37.8	34.5	27.8	17.3	59.0	49.7	26.1	13.5	20.7
■ TL Cr (mm)	110	115	113	105	99	134	126	106	96	102

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
× avg. K (year)	0.39	0.33	0.30	0.32	0.37	0.38	0.38	0.30	0.30	0.36
— M (B&H (1.6))	0.63	0.53	0.48	0.51	0.59	0.61	0.60	0.48	0.48	0.57
+ avg. Z (year)	1.61	1.35	1.35	1.35	1.95	1.27	1.31	1.37	1.73	1.68
✳ E (1.6)	0.61	0.61	0.64	0.62	0.70	0.52	0.54	0.65	0.72	0.66

Fig. 1 – Demographic parameters estimated for the cohorts from 1993 to 2002 and outputs of the pool dynamic model.

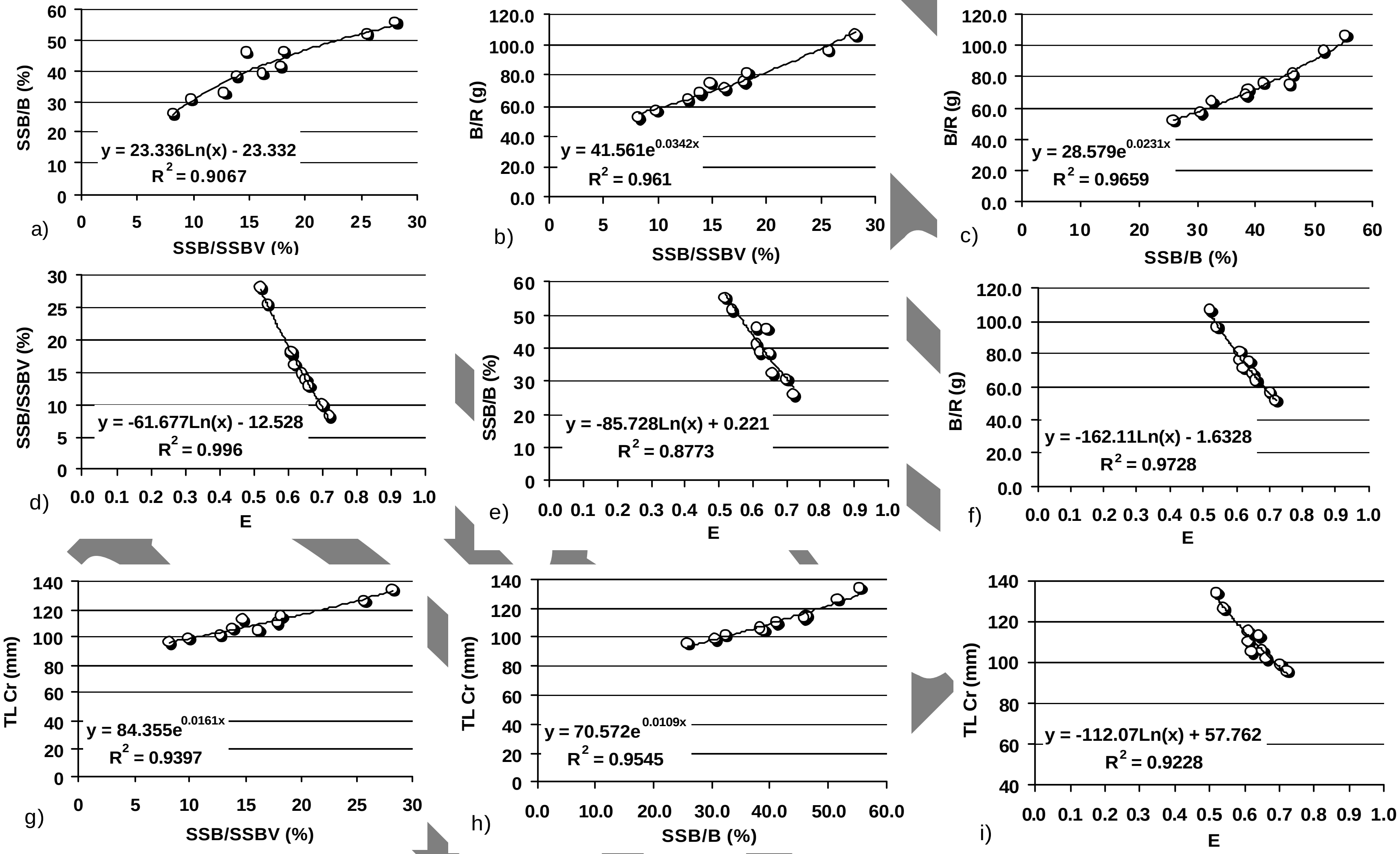

Fig. 2 – Relationships between the indicators and reference points derived by the pool dynamic model and from trawl surveys (E).

ACOUSTIC ESTIMATES OF SMALL PELAGIC FISH STOCKS IN THE EASTERN PART OF ADRIATIC SEA.

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Abstract

Following positive experience gained during 1st joint Croatian-Italian-Slovenian acoustic survey, organised within the framework of the FAO-AdriaMed Project in the northern part of Adriatic Sea, Croatian Ministry of Agriculture, Forestry and Water Management and its Directorate of Fisheries has organised in cooperation with Institute of Oceanography and Fisheries in Split, an acoustic survey on small pelagic fish combined with environmental monitoring along the eastern part of Adriatic Sea, called PELMON programme. Results of environmental monitoring were in accordance with usual situation present on the eastern part of Adriatic Sea in autumn. However, despite the fact that in this survey, carried out in September 2003, approximately just half of GSA 17 was covered by acoustic sampling, it was noticed that even these partial fisheries independent estimates of sardine biomass were significantly higher than the figures from the most recent VPA stock assessment in the entire Adriatic Sea area for the 2002 year.

Keywords: acoustic survey, Adriatic Sea, environmental monitoring, small pelagic fish

1. Introduction

Pelagic fishery in Adriatic Sea, as well as in other major fishery areas in the world, must face the problem of the enormous instability of small pelagic fish resources, either because of fishing pressure or the variety of environmental factors that affect both recruitment and mortality rates.

The most important small pelagic fish species in the Adriatic are anchovy, sardine and sprat. During the last 15 years of 20th century, a series of dramatic changes in species composition and their biomass have been observed in the eastern part of Adriatic sea. Therefore, besides multi-species character of the small pelagic fisheries in Adriatic Sea, it is of the highest importance to understand nature of these changes in order to make possible an adaptive fishery management.

At present, the acoustic methodology of fish stock assessment is the only efficient tool to be used in answering to such a simple but crucial question for fishery management:

How much fish of species X is in an area Y at a given time?

However, "nothing simple is ever easy". Answer on this question is crucial, but it is not enough to understand all changes in the pelagic communities. For this reason, an Ecosystem Approach to Fisheries (EAF) seems to be the most appropriate for the identification of specific environmental and biological interactions between small pelagic fish and its environment.

It is well known that VPA is one of the most efficient and most frequently used indirect methods for stock assessment. It is also known that this method is based on fishery-dependent data (such as catch and effort statistics), age structure of the catch and "guesstimates" of mortality rates (Spare and Venema, 1992; Lleonart, 2002). However, sometimes reliability of official catch and effort statistics data might be very questionable, as noticed by Ticina and Giovanardi (1997) for small pelagic fishery in the northern Adriatic Sea. In addition to differences caused by use of different fishing gears, such as pelagic trawls and purse seines, there are also huge differences in CPUE between pelagic trawls used on western and eastern coast of Adriatic Sea (Ticina and Giovanardi, 1997; Ticina *et al*., 1999). Furthermore, biomass estimate (yield by VPA) is very sensitive to some of variables such as the natural mortality, a parameter that can not be directly measured but only estimated. Finally, this is a single-specie approach that might face with difficulties to describe what is going on in multi-species and multi-gear pelagic fisheries.

On the other hand, following positive experience gained during 1st joint Croatian-Italian-Slovenian echo-survey, organised within the framework of the FAO-AdriaMed Project in the northern part of Adriatic Sea (Azzali *et al*., in press), Croatian Ministry of Agriculture, Forestry and Water Management and its Directorate of Fisheries have organised, in cooperation with the Institute of Oceanography and Fisheries in Split, the acoustic survey of small pelagic fish combined with environmental monitoring along the eastern part of Adriatic Sea, called PELMON programme (www.izor.hr/pelmon/).

Despite very high cost of such multidisciplinary approach, it is believed that fisheries-independent stock assessments for small pelagic fish should be used for fishery management purposes. Also, acoustic surveys if combined with environmental monitoring, beside the most updated estimates, provide the most complete picture of the situation that we have under sea surface, thus creating a base for future ecosystem approach to fisheries management. Based on all these facts, Croatian Ministry of Agriculture, Forestry and Water Management decided to take the results of acoustic survey combined with environmental monitoring as a base for future long-term sustainable management of this part of the common and shared Adriatic resources.

2. Study area

The study area of PELMON programme occupies eastern part of GSA 17 (GFCM, 2001), and extends from eastern coast of Adriatic Sea, between cape Savudrija in the north and cape Oštro in the south, up to middle line or bathimetry of 200 m. Based on geo-morphological differences, this area is divided into two sub-areas:

1) channel waters
2) open sea

Furthermore, channel waters are divided into northern part and southern part, while open sea sub-area is divided into northern, middle and southern parts by extending existing area division used during previous acoustic surveys on Italian side of Adriatic Sea (Fig. 1).

3. Methodology

Target species in this research were anchovy (*Engraulis encrasicolus* L.), sardine (*Sardina pilchardus*, WALB.) and sprat (*Sprattus sprattus* L.). All other pelagic species were considered within a common category called "other pelagic species".

Acoustic sampling have been carried out using the last generation of scientific sounders, SIMRAD EK60 based on split beam technology, with frequency of 38 kHz. Echo-sounder receives the vessel navigation data from a standard GPS. Acoustic samples were collected using a hull-mounted transducer (SIMRAD ES38B) on research vessel "BIOS", and recorded on hard disc and CD media and processed with BI500 post-processing software (Simrad, 1999).

To ensure the high accuracy of acoustic measurements, before the survey, the equipment was calibrated using the standard target (copper sphere, 60 mm in diameter, density 8945 kg/m3, TS = -33.6 dB), following standard procedures (McLennan and Simmonds, 1992).

In the open sea, acoustic data were collected along partially random positioned parallel transects with inter-transect spacing of 10 nm, while transects in the channel area were positioned regarding to geomorphology features (Figure 2). Measured values of acoustic data, referring to nautical area scattering coefficient (i.e. backscattering area per sea surface), are expressed as S_A-values (Simrad, 1996). These measured S_A-values were converted into fish biomass density (t/nm^2) based on the equations used during previous echo surveys on Italian side of Adriatic Sea (Azzali, *et al.* 1997; Azzali *et al.*, in press).

In order to identify different acoustic targets, small pelagic trawl was used to sample fish, while zooplankton samples were taken by Nansen-net equipped with closing mechanism. Beside identification of acoustic targets, these collected samples were used to get information about fish size structure, nutrition and zooplankton communities.

Environmental monitoring included sea-water sampling by standard Nansen-bottles at standard oceanographic depths, and CDT profiles made by IDRONAUT 316 and/or SEABIRD 25 multisonde. In addition to phytoplankton community and chlorophyll *a* concentration monitoring, the dissolved oxygen concentration was determined. Temperature and salinity measurements, beside all other purposes, were used to calculate and regularly update sound speed in the sea during the survey.

4. Results and discussions

4. 1. Environmental characteristics and spatial distributions of target species

Results of environmental monitoring are in accordance with usual situation present on the eastern part of Adriatic Sea in autumn. Average values of temperature and salinity in water column as measured on different sampling stations from different parts of study area are given in Table 1. Oxygen saturation within entire study area varied from 88% to 121%, following typical seasonal situation in the Adriatic Sea. Higher phytoplankton biomass was noticed in the northern parts of channel area and open sea than in the other parts of study area (Figure 3), followed also by the highest densities of mezozooplankton (Figure 4). Among mezozooplankton organisms, copepod species (in particular *Temora stylifera* and *Microsetella norvegica*) were the most abundant items found in the fish stomachs.

Based on collected acoustic data and acoustic targets identification information, spatial distribution of target species were determined using GIS objective analyses methodology (Brasseur, 1994; Geoferry and Thang, 1996). Spatial distributions of target species within study area in September 2003 are shown in the Figures 5-7.

4. 1. 1. Anchovy, *Engraulis encrasicolus* L.

Following the determined spatial distribution, it is obvious that during survey period, a part of anchovy population was distributed outside study area, particularly in the northern part of Adriatic Sea. The smallest specimens of anchovy (LT = 2.0-2.5 cm) were the most abundant within southern part of channel area (Figure 8). Beside this ("bianchetto"-size) juvenile anchovy, other specimens ranged from 6.5 to 16.5 cm in

total length, with average length of 9.28 cm. Length frequency distribution were bimodal (Figure 9), with modal values at 10.0 and 13.0 cm respectively. Calculated length-weight relationship was:
$W = 0.0025 \times LT^{3.341}$ (r^2=0,9862).
Biomass density of anchovy population within study area was estimated from measured S_A-values during the survey taking into account information about targets size structure obtained from collected samples. Furthermore, total biomass was calculated by multiplication of fish density by area surface. Estimates of anchovy biomass (with corresponding 95% confidence interval) within each area are shown in the Table 2.

4. 1. 2. Sardine, *Sardina pilchardus* WALB.

It was noticed that in September 2003 the bulk of sardine population was found in the northern part of Adriatic Sea, along the western coast of Istrian peninsula. Total body length of sardines ranged from 7.5 to 18.5 cm, with an average value of 13.88 cm. However, length frequency distribution was bi-modal (Figure 10), with modal values at 9.5 and 16.5 cm respectively. Calculated length-weight relationship was:
$W = 0.0028 \times LT^{3.381}$ (r^2=0,9960).
Biomass density of sardine population within study area was estimated from measured S_A-values during the survey taking into account information about targets size structure obtained from collected samples. Furthermore, total biomass was calculated from fish densities data as related to the surface area surveyed.. Estimates of sardine biomass (with corresponding 95% confidence interval) within each area are shown in the Table 3.

4. 1. 3. Sprat, *Sprattus sprattus* L.

Spatial distribution of sprat population suggests that during survey period a part of its population was distributed outside study area, that is in accordance with sprat's migration pattern in northern part of Adriatic Sea as described by Ticina (2000). Within the study area, sprats were detected only in the northern part of open sea. In the remaining part of study area, sprats were not detected. Since only a few specimens were fished, no length frequency distribution nor length-weight relationship was calculated.
Biomass density of sprat population within study area was estimated from measured S_A-values during the survey, taking into account average target size obtained from collected samples. Furthermore, total biomass was calculated by multiplication of fish density by surface area. Estimates of sprat biomass (with corresponding 95% confidence interval) within the study area are shown in the Table 4.
Being migratory species that change their spatial distribution patterns during the year, biomass of anchovy, sardine and sprat normally change within each particular sub-area following their migratory patterns. As already noticed during the pilot Joint Echo-Survey in the Northern part of the Adriatic Sea (Azzali *et all.*, in press), it is very important to cover the entire distribution area of a target species by sampling activities (i.e. Adriatic Sea) if complete biomass estimate is to be obtained.
However, even if these partial estimates of sardine biomass are compared with results of the most recent VPA stock assessment made by Cingolani *et al.* (2003), one can notice that VPA estimates for the entire Adriatic in the 2002 year are much lower than these statistically independent biomass estimates.
It seems that the most recent VPA studies for Adriatic area, might include some sources of biases such as questionable reliability of catch statistic data, discards and "bianchetto" fishing. Perhaps, fishing effort standardization should also be done, taking

into account large differences in performances between “same type” fishing gear (i.e. pelagic trawls) currently used all along the eastern and western coasts of Adriatic Sea (Ticina and Giovanardi, 1997; Ticina *et al*., 1999). However, despite of these possible biases that might cause a certain underestimations of stock biomass, observed historical trends are very useful in describing natural fluctuations of these pelagic stocks biomass in the Adriatic Sea.

It is very likely that in the near future the fisheries independent acoustic estimates of anchovy, sardine and sprat stocks from entire Adratic Sea will be available. If so, these independent estimates might be taken into account with aim to tune future VPA stock assessments of these species (Gavaris, 1988; Lassen and Medley, 2001; Spare and Venema, 1992).

5. Instead of conclusions

Being aware that acoustic surveys along the eastern part of Adriatic Sea were initiated only two years ago, long data series to observe trends in biomass and/or changes in environmental parameters are not available. However, it is important to point out the following (for Adriatic Sea area):

1) If independently obtained biomass estimates of small pelagic fish from acoustic surveys are available, the tuning of VPA to improve accuracy of final results is to be recommend.

2) International scientific cooperation within regional projects (such as FAO-AdriaMed, EU-INTERREG, EU-MEDITS…) is very important in constructing framework for joint international researches (that should cover the entire Adriatic area) and long-term sustainable management of common and shared fish stocks.

3) It should be recommended that GFCM encourage and support international fisheries independent stocks biomass assessments combined with environmental monitoring, as a principal tool for an adaptive, ecosystem based common fisheries management over the entire area of the Adriatic Sea.

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Figure 1. Study area devided into five sub-areas.

Figure 2. Partially random positioned acoustic transects within study area.

Figure 3. Concentrations of chlorophyll a in different parts of study area (September, 2003).

Figure 4. Abundance of zooplankton within study area (September, 2003).

Figure 5. Spatial distributions of anchovy within study area in September 2003.

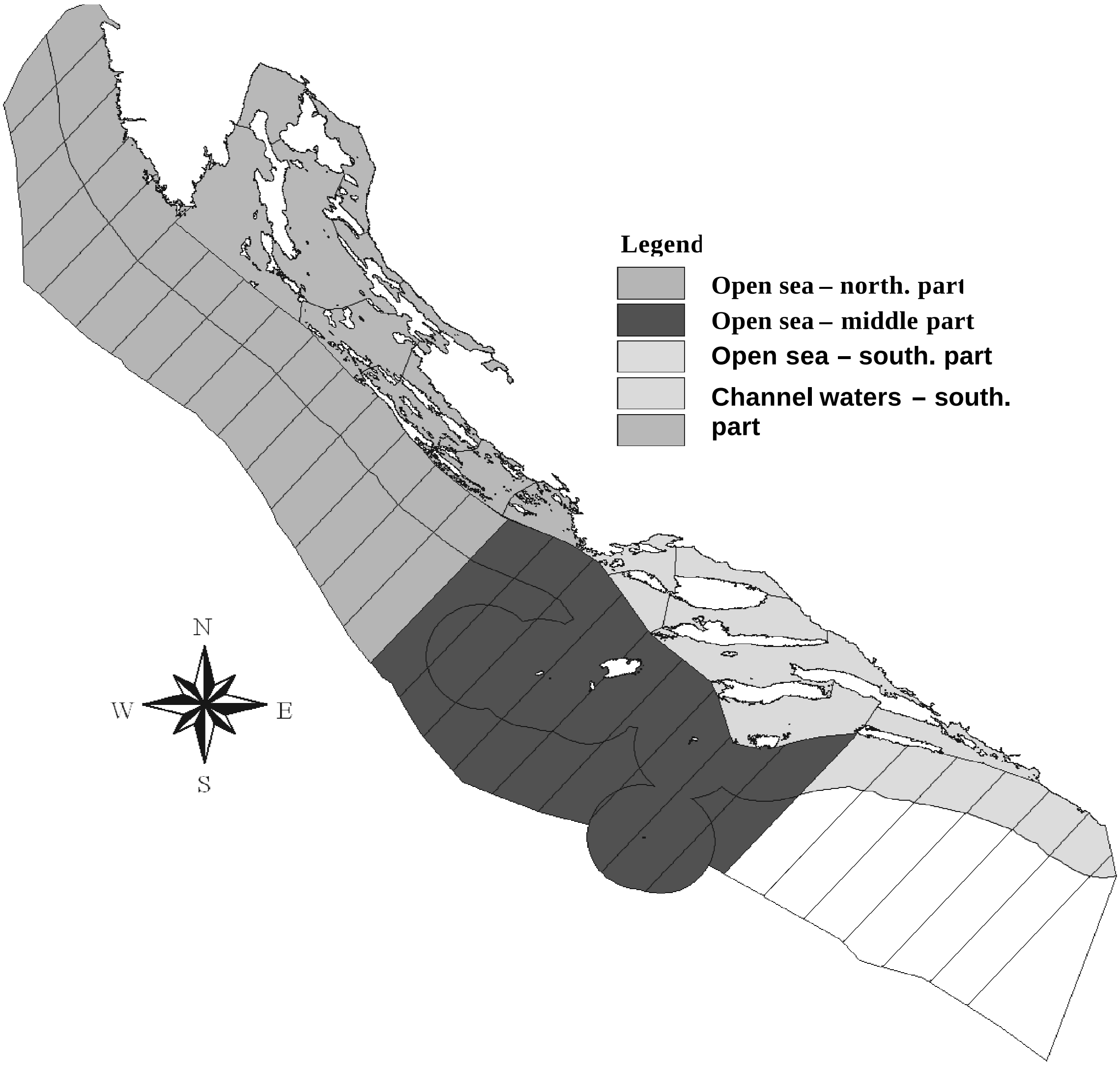
Figure 6. Spatial distributions of sardine within study area in September 2003

Figure 7. Spatial distributions of sprat within study area in September 2003

Figure 8. Juvenile specimen of anchovy from southern part of channel area(September, 2003).

Figure 9. Length frequency distribution with respective weight portions of anchovy (LT>6cm) in the study area (September, 2003).

Figure 10. Length frequency distribution with respective weight portions of sardine in the study area (September, 2003).



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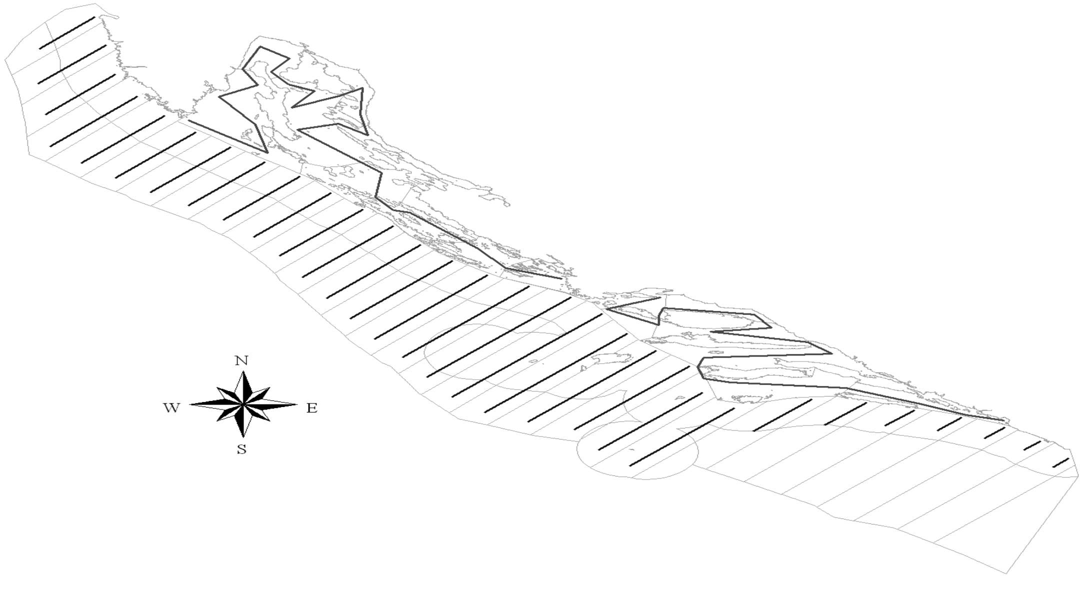

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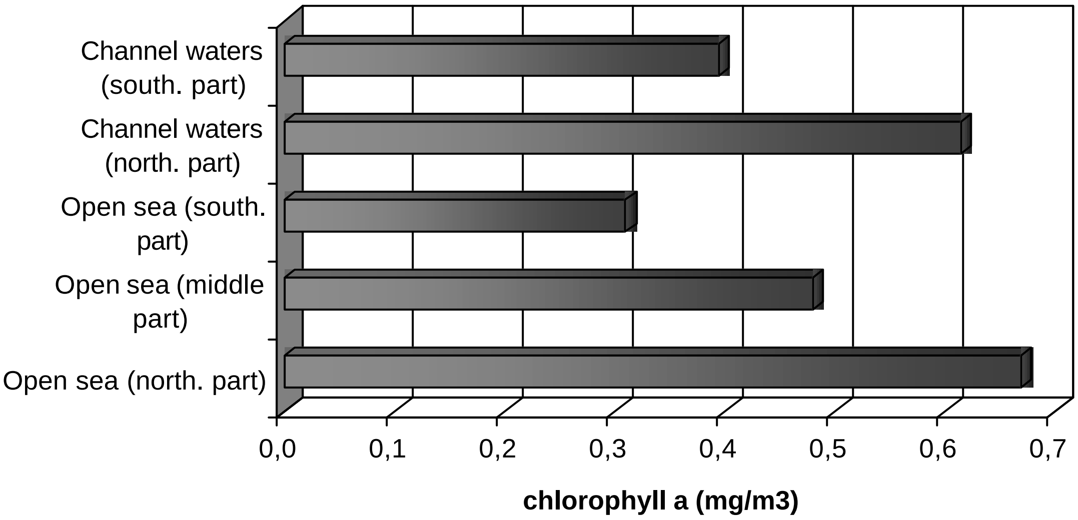

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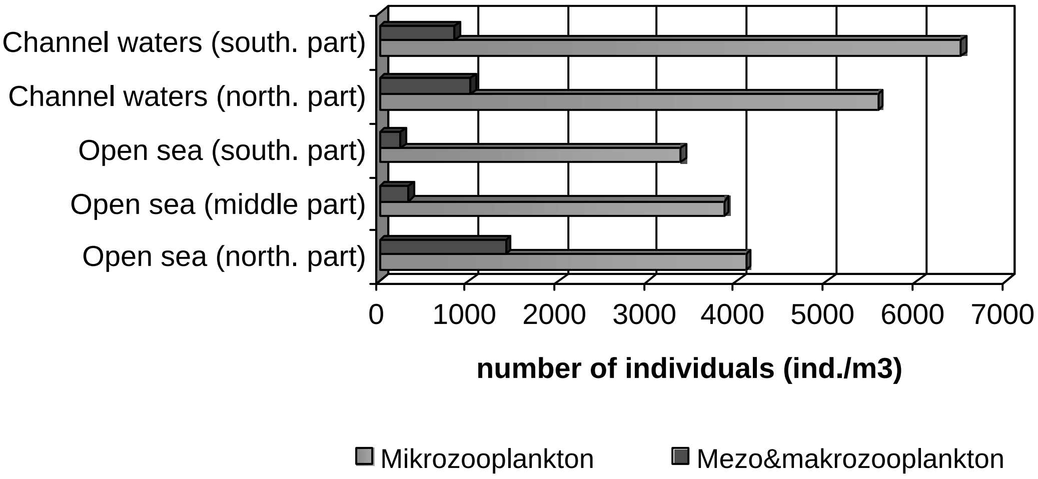

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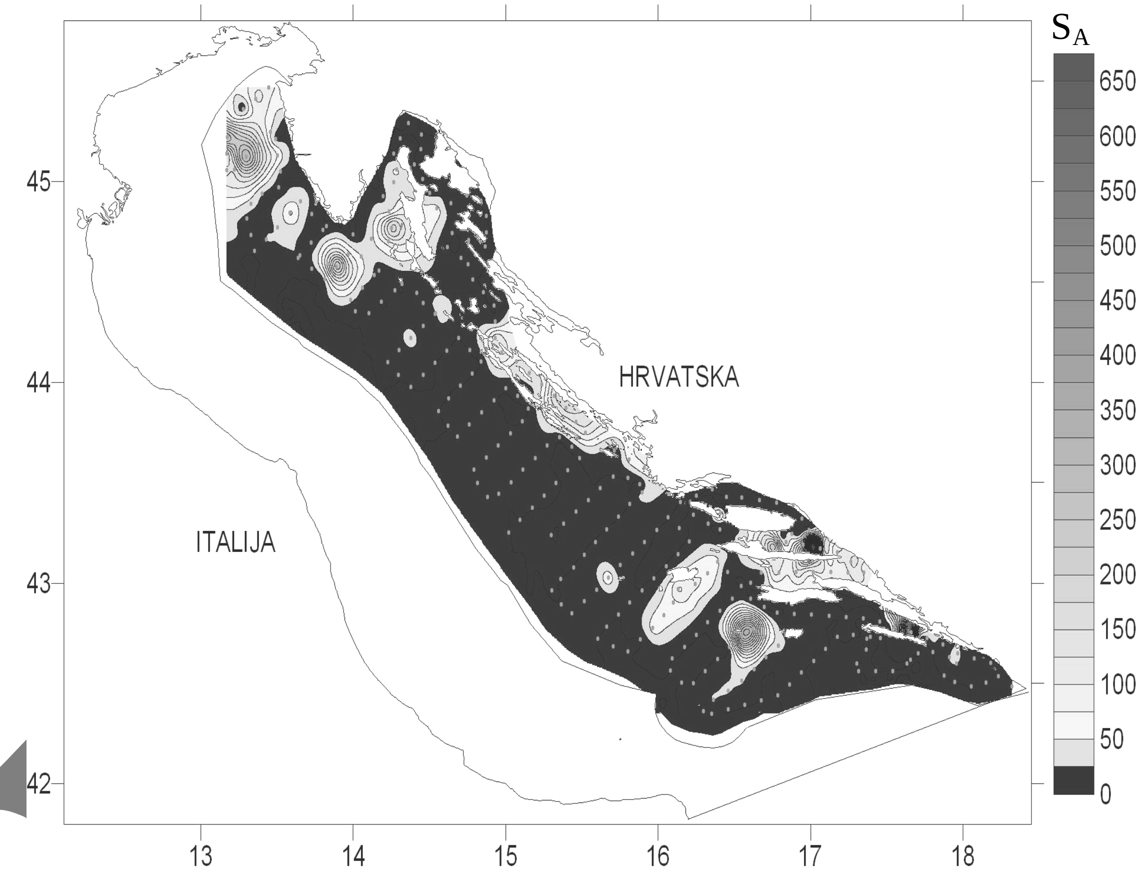

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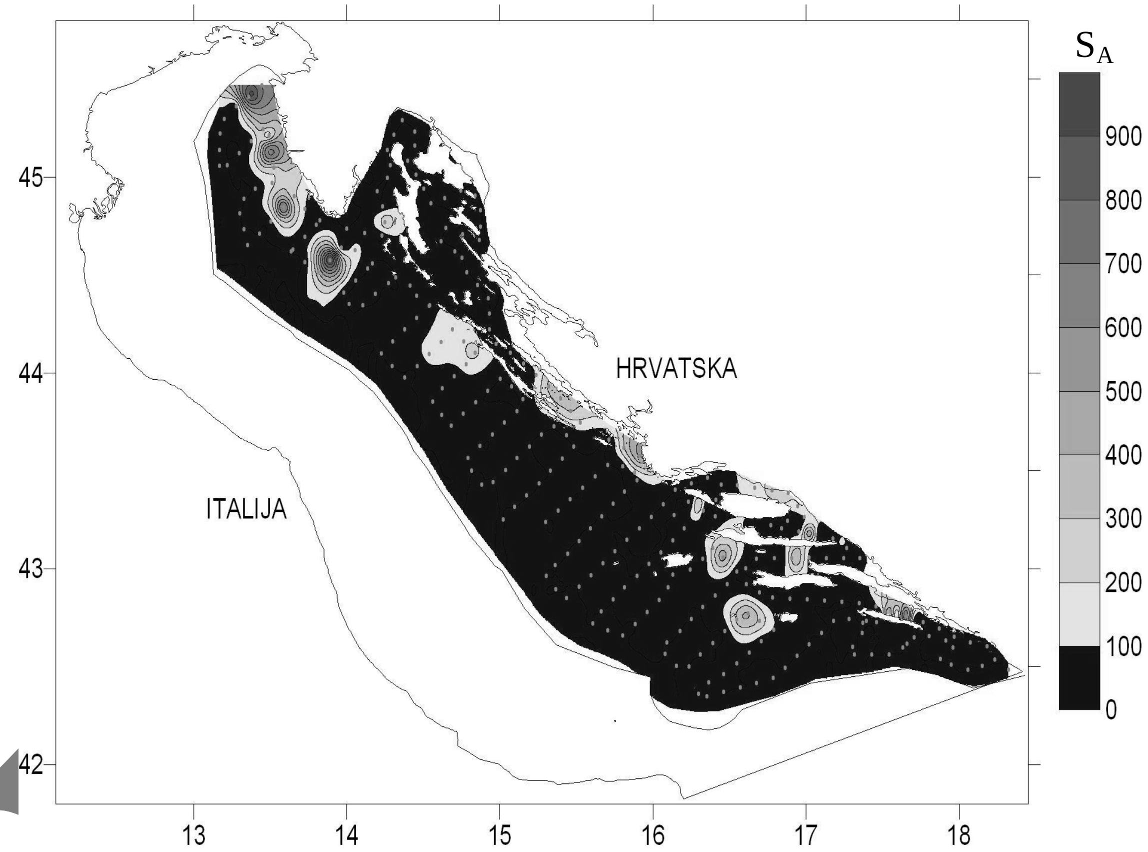
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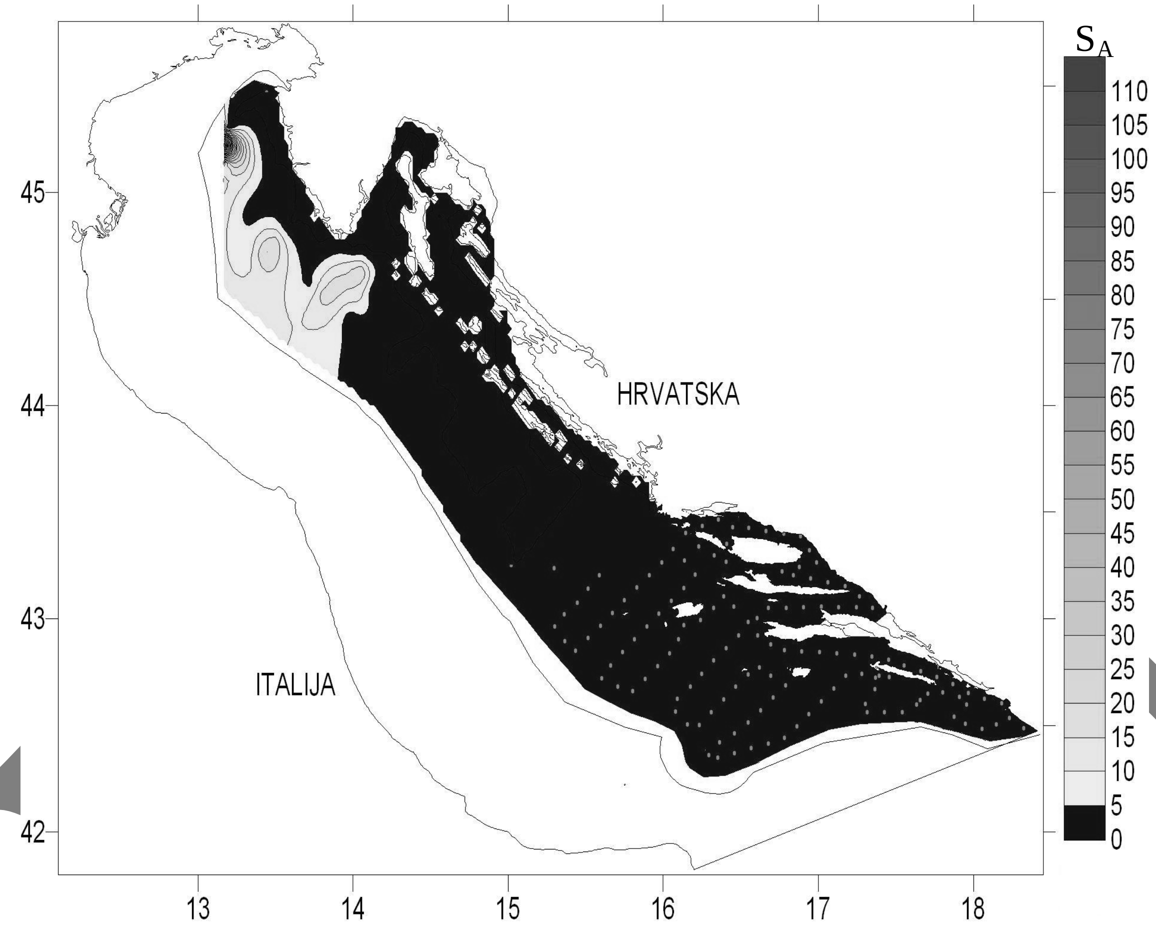

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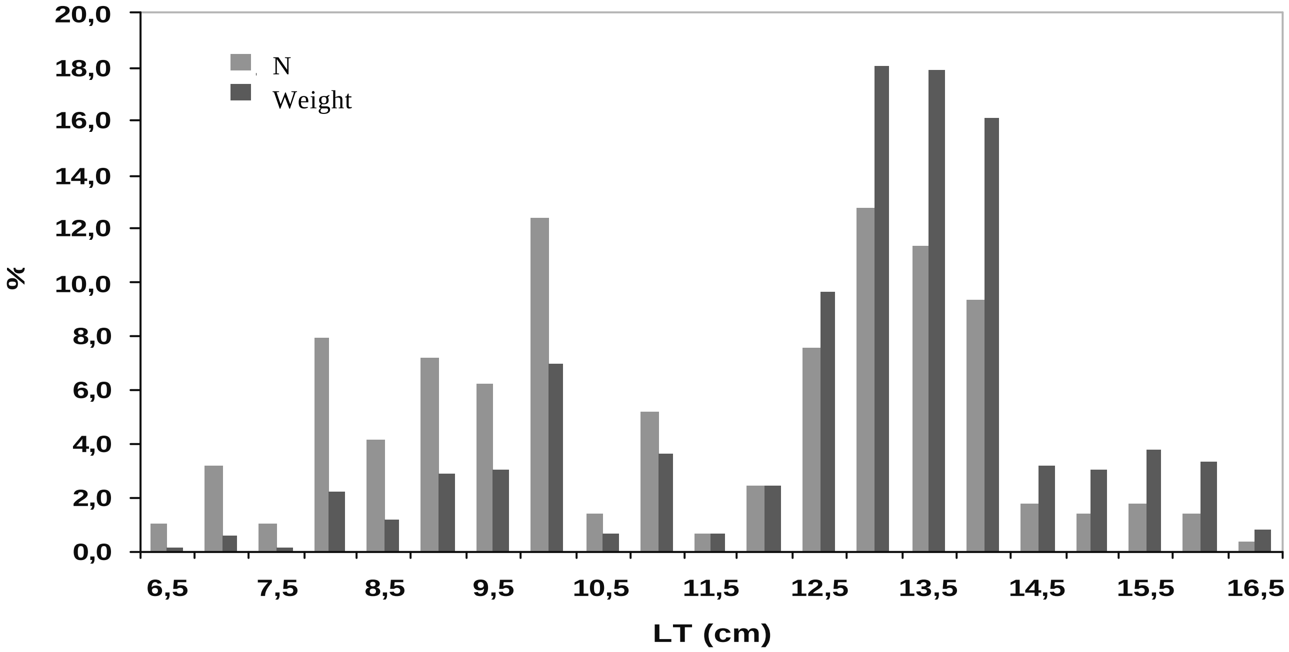

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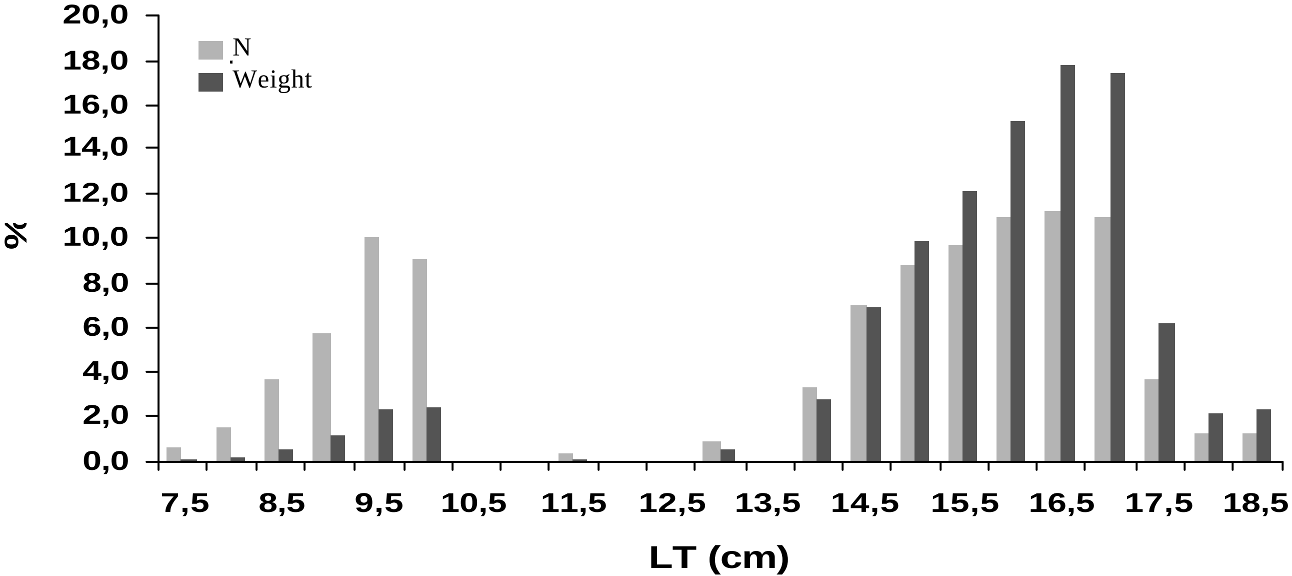

Figure 10.

TABLES

Table 1. Average values of temperature and salinity in water column as measured on different sampling stations within study area (Septemper, 2003).

Sampling positions	Depth (m)	$\text{Sal}_{(avg)}$ ‰	$\text{T}_{(avg)}$ °C	***Area***
43°47.06'N / 15°28.76'E	83	38.70	17.69	Channel waters (north. part)
44°17.91'N / 14°55.80'E	60	38.53	16.71	Channel waters (north. part)
44°35.83'N / 14°44.79'E	76	38.42	16.82	Channel waters (north. part)
44°55.64'N / 14°11.82'E	28	37.99	20.19	Channel waters (north. part)
44°28.28'N / 14°29.34'E	51	38.74	19.66	Channel waters (north. part)
42°49.72'N / 17°15.14'E	79	38.78	19.07	Channel waters (south. part)
43°15.98'N / 17°00.14'E	63	38.65	18.89	Channel waters (south. part)
42°47.46'N / 17°30.29'E	78	38.78	18.55	Channel waters (south. part)
43°03.15'N / 17°21.22'E	36	38.47	21.63	Channel waters (south. part)
43°28.42'N / 16°22.78'E	65	38.63	18.81	Channel waters (south. part)
45°21.85'N / 13°17.50'E	28	38.08	19.95	Open sea (northern part)
44°56.09'N / 13°22.58'E	37	38.59	21.59	Open sea (northern part)
44°46.19'N / 13°30.19'E	41	38.60	22.44	Open sea (northern part)
44°37.50'N / 13°38.40'E	44	38.36	19.54	Open sea (northern part)
44°30.88'N / 13°48.53'E	40	38.58	21.15	Open sea (northern part)
44°32.30'N / 14°09.90'E	48	38.63	21.18	Open sea (northern part)
44°11.69'N / 14°20.58'E	65	38.64	17.64	Open sea (northern part)
44°07.44'N / 14°47.98'E	62	38.73	19.11	Open sea (northern part)
43°40.63'N / 14°56.36'E	87	38.87	18.16	Open sea (northern part)
43°38.43'N / 15°29.54'E	166	38.76	16.79	Open sea (northern part)
43°29.72'N / 15°51.48'E	152	38.73	16.56	Open sea (middle part)
42°59.65'N / 16°14.22'E	113	38.85	16.90	Open sea (middle part)
42°58.51'N / 16°32.91'E	92	38.79	18.72	Open sea (middle part)
42°46.38'N / 16°39.27'E	117	38.86	17.52	Open sea (middle part)
43°07.39'N / 15°47.92'E	126	38.86	16.61	Open sea (middle part)
42°22.76'N / 16°18.79'E	67	38.83	18.03	Open sea (middle part)
42°26.91'N / 16°47.35'E	202	38.85	15.54	Open sea (middle part)
42°37.11'N / 17°39.48'E	150	38.81	16.83	Open sea (southern part)
42°23.40'N / 18°18.60'E	195	38.85	16.58	Open sea (southern part)
42°34.44'N / 18°09.04'E	111	38.81	17.59	Open sea (southern part)

Table 2. Estimations of anchovy biomass (t) with respective 95%CI limits within study area (September, 2003).

AREA:	Lower CI limit	Biomass estimates	Upper CI limit
Channel waters – north. part	8.174	13.708	19.246
Channel waters – south. part	6.295	9.520	12.745
Open sea – north. part	12.291	20.611	28.932

Open sea – middle part	**5.577**	**11.855**	**18.133**
Open sea – south. part	**135**	**529**	**924**
Entire study area:	**32.472**	**56.223**	**79.980**

Table 3. Estimations of sardine biomass (t) with respective 95%CI limits within study area (September, 2003).

AREA:	Lower CI limit	Average value	Upper CI limit
Channel waters – north. part	15.027	37.042	59.058
Channel waters – south. part	19.702	28.146	36.590
Open sea – north. part	56.651	115.088	171.511
Open sea – middle part	10.748	33.290	55.832
Open sea – south. part	75	850	1.626
Entire study area:	102.203	214.416	324.617

Table 4. Estimations of sprat biomass (t) with respective 95%CI limits within study area (September, 2003).

AREA:	Lower CI limit	Average value	Upper CI limit
Channel waters – north. part	0	0	0
Channel waters – south. part	**0**	**0**	**0**
Open sea – north. part	**1.688**	**5.259**	**8.830**
Open sea – middle part	**0**	**0**	**0**
Open sea – south. part	**0**	**0**	**0**
Entire study area:	**1.688**	**5.259**	**8.830**

ON THE SUITABILITY OF SOME INDICATORS FROM TRAWL SURVEYS DATA. MEDITERRANEAN GEOGRAPHICAL SUB-AREA N° 18

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***FAO-AdriaMed, Termoli (Italy). E-mail: piero.mannini@fao.org

Abstract

The suitability of some indicators from bottom trawl surveys carried out in the southern Adriatic Sea (GFCM – Mediterranean geographical sub-area 18) was investigated using data available from the Medits programme (years 1996-2003). The trajectories of some population indicators such us arithmetic and geometric mean, median, and 75th percentile, were analysed for two main “target” fishery species: the European hake and the Deep-water rose shrimp. Species’ spatial and temporal variations have been also considered. Furthermore, some of the indicators concerned and the BOI index (bottom-dwelling fish and overall fish ratio) were applied to the pool of Medits target species. The results of this exercise highlight the potential suitability of some of the indicators given, at least for the investigated area and time period.

Introduction

The identification and use of suitable indicators and their reference points for fisheries management is nowadays a central issue worldwide. The debate particularly focuses on what, when and where indicators can be best applied.

In this preliminary work the suitability of some indicators from bottom trawl surveys is considered using data available from the Medits programme carried out in the southern Adriatic Sea (GFCM – Mediterranean geographical sub-area 18) from 1996 to 2003.

The aim was to identify a first set of simple indicators characterised by the following desirable properties:

- Scientific validity in the sense they should be indicative of the objective they intend to reflect;
- Easy compilation and processing procedures;
- Minimization of basic assumptions;
- Reliable performance with respect to interactions between fishery, environment and resources;
- Applicability to different scenarios and capability to show response to management measures;
- Feasibility and cost-effectiveness in terms of data collection requirement;
- Comprehensibility and acceptability by all stakeholders;
- Easy integration and comparison to each other and with indicators from other sources (e.g. indirect methods, fishery-dependant information, economic and environmental indicators, etc.).

The scientific background and some proposed indicators presented are mostly based on the work of Bellail *et al*. (2003), Caddy (1999, 2002), FAO Fishery Resources Division (1999), Gristina *et al*. (in press), Hall and Mainprize (2004), Hutchings (1996), Koeller *et al*. (2000).

Material and Methods

Raw data were obtained from experimental trawl hauls carried out in the GFCM GSA 18 during the period 1996-2003 (Figure 1). The trawl surveys have been carried out during spring-summer season, in the framework of the EC MEDITS Programme, according to a specified protocol (Bertrand *et al*., 2002).

The catch data were standardised by using the swept-area method (Sparre & Venema, 1992) in order to obtain biomass (kg/km^2) and abundance (n°/km^2) indices.

Selected indicators were applied both to single species populations and to pooled demersal fishery species. The European hake (long-lived species) and the Deep-water rose shrimp (short-lived species) have been selected for the first case, all the fish species and the MEDITS' target species reference list (short list) for the second (Bertrand et al., 2002).

The following indicators have been tested:

- Arithmetic mean of catch indices, weighted by stratum area (Cochran, 1977 in Souplet, 1995). Mediterranean hake, Deep-water rose shrimp and the MEDITS' target species reference list.
- Geometric mean of catch indices, weighted by stratum area (Cochran, 1977 in Souplet, 1995). Mediterranean hake, Deep-water rose shrimp and the MEDITS' target species reference list.
- Median value of catch indices. Mediterranean hake, Deep-water rose shrimp and the MEDITS' target species reference list.
- 75th percentile value of catch indices. Mediterranean hake, Deep-water rose shrimp and the MEDITS' target species reference list.
- Mean length. Mediterranean hake, Deep-water rose shrimp.
- Spatial distribution (mapping by GIS; exponential model kriging). Mediterranean hake, Deep-water rose shrimp.
- BOI, bottom-dwelling fish/overall fish ratio index (mean value). The bottom-dwelling species were chosen according to some morphological characteristics (Gristina *et al*., in press). All the collected fish species were included in the computation, excluding pelagic species belonging to the families Clupeidae, Carangidae, Engraulididae and Scombridae.

Results and Discussion

The results related to both the single species (*M. merluccius*, *P. longirostris*) and the pool of Medits' species highlight the following:

- The trajectories of most of the chosen indicators are decreasing for the European hake. The decrease seems to be better indicated by the trend of biomass indices with respect to the abundance ones. The best fitting of linear trend (indicative of possible direction) resulted from the use of the 75th percentile (Figure 2 and 3). No trend could be estimated for the mean length indicator (Figure 3).

- The trajectories of most of the chosen indicators are increasing for the Deep-water rose shrimp. The increase seems to be better indicated by the trend of biomass indices with respect to the abundance ones, as it was reported for European hake. The best fitting of linear trend (indicative of possible direction) resulted from the use of the 75th percentile (Figure 2 and 3), as in the case of the European hake. No trend could be estimated for the mean length indicator (Figure 3).
- The trajectories of most of the chosen indicators for the pool of Medits' species highlighted a stability of the values (Figure 4).
- The BOI mean index for the whole GSA 18 seems to increase in the investigated time period. Nevertheless, the increase was related mostly to the shelf bottoms while fluctuating trend was recorded for slope bottoms (Figure 5).
- Spatial distribution. The yearly maps of biomass/abundance distributions of *M. merluccius* and *P. longirostris* seem to confirm the species indicators' trajectories reported above. In fact, the European hake appears both to be undergoing an overall decrease and a reduction of its occurrence area (increase of "blank" zones) (Figure 6 and 7). Moreover, the distribution of individual mean weight at six years interval showed a decrease of the higher values (presence of larger specimens in the trawl catches) (Figure 8). Unlike the European hake, the yearly maps of the Deep-water rose shrimp indicate the increase of this resource in the GSA 18 and particularly the evident colonization of the whole basin during the last reported years (Figure 9 and 10).

Moreover, below is reported A brief discussion and some comments on the application and performance of each indicator applied to the single species or species group are given below:

- Arithmetic mean. Low reliability. The arithmetic mean value can be strongly influenced by skewed distributions (i.e. few tows with large catch), as widely reported in literature (Conquest *et al.*, 1996; Hutchings, 1996; McConnaughey and Conquest, 1992; Pennington, 1996). Moreover, the precision estimators (i.e. variation coefficient) seem to be mostly influenced by sampling density, masking the supposed increase of variance expected as a consequence of increasingly higher exploitation rates (Blanchard & Boucher, 2001).
- Geometric mean. Probably good reliability. It could be used jointly with other indicators, in order to integrate the information (Hutchings, 1996).
- Median value. It seems to react well to the dynamics of the resources, however it might be more appropriate for those species with large occurrence in the samples. It is suitable to apply this together with other indicators, in order to integrate the information.
- 75th percentile. Same as for the median. It would appear to give a better and more timely indication on the biomass trajectory with respect to geometric mean and median Moreover, the indicator highlights the fraction of the medium-high catches for the species, which is very important for the sustainability of fishery exploitation. It should be used together with other indicators, in order to integrate the information.

- Mean length (population). Very low reliability. Strongly influenced by the fishing gear selectivity and recruitment strength (Bellail *et al.*, 2003).
- Spatial distribution. It could be a powerful tool if integrated with other indicators. It has been hypothesised that temporal modification of spatial distribution patterns can be considered as an indicator of resource condition (Hutchings, 1996). Moreover, if the bio-ecology of the species is known, the spatio-temporal distribution of individual mean weight index could provide additional information on the consistency of the spawner fraction.
- BOI. The BOI index did not perform well in the investigated scenario where industrial fishery has been a well-developed activity for some time. The index can probably be applied on long-time series, or for the comparison between areas characterised by marked differences in fishery exploitation.

1.General considerations:

- Standard survey protocol (same sampling design, haul density, period, etc.) allows for more reliable comparison in the case of most of the indicators used (Bellail *et al.*, 2003).
- In general, the numerical abundance index (n/km^2) performs poorly. As Mediterranean bottom trawl fisheries mostly exploit juveniles, the recruitment strength and intensity probably limit the significance of this indicator. The same would apply when using the mean length as an indicator. Nevertheless, the “abundance “ indicator could be taken in consideration as additional information for the explanation of the observed data.
- In most cases, population related indicators should be applied to species with high occurrence in the survey catches (high reliability may be expected to be achieved with frequency > 50%).

2. Some hypotheses on the trend observed:

- European hake. The decreasing trend of biomass indices appears mostly related to the adult fraction of the population. Some possible causes of such a decrease could be linked to the overexploitation of large individuals by bottom long-liners (De Zio *et al.*, 1998) and/or the increase of fishing effort in the eastern Adriatic sector (Mannini & Massa, 2000). In any case, deeper investigation is needed to explain the obtained results.
- Deep-water rose shrimp. The increasing trend of biomass indices is observed together with the reported expansion of geographical occurrence (i.e. GSA 18). Some possible causes of such an increase could be linked to the effects of environmental conditions (i.e. increase of bottom temperature) (Ungaro and Gramolini, submitted) and/or to the variation of inter-specific ratios (predator-prey relationships?).
- Pool of target species. The supposed stability could be linked to inter-specific compensation (single species variation higher than total species variability), as well as to the influence (variation) of the main environmental parameters and the modifications of predator-prey relationships.

Conclusions

The trajectories of some population indicators such us arithmetic and geometric mean, median, and 75th percentile, were analysed for both biomass and abundance indices based on trawl survey data (Medits surveys). Two main target species for the south Adriatic demersal fishery, the European hake and the Deep-water rose shrimp were investigated. Species spatial and temporal variations have been also considered.

Furthermore, some of the indicators concerned were applied to the pool of Medits target species to outline the interactions within the typical Mediterranean multi-species fishery. For the same reason, the BOI (bottom-dwelling fish and overall fish ratio index) was also used.

The results of this exercise highlight the potential suitability of some of the indicators given, at least for the investigated area and time period. Further appraisal of the performance of the indicators concerned should be carried out applying them to a larger set of selected species.

The proposed indicators from fishery-independent direct methods could be useful to establish a wider multidisciplinary poly-indicator score panel for the Adriatic Sea fisheries. In this respect, also owing to the shared nature of Adriatic fishery stocks, the FAO-AdriaMed Project can provide the necessary regional cooperation framework.

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Figure 1 - Investigated area, Gsa 18.

Figure 2 - Trajectories of the chosen indicators for the European hake (on the left) and Deep-water rose Shrimp (on the right).

Figure 3 - Trajectories of the chosen indicators for the European hake (on the left) and Deep-water rose Shrimp (on the right).

Figure 4 - Trajectories of the chosen indicators for the pool of MEDITS species.

Figure 5 - Trajectories of the mean BOI index.

Figure 6 - Spatial distribution of biomass index (Kg/Km^2) for Mediterranean hake (from 1996 to 2003).

Figure 7 - Spatial distribution of abundance index (N/Km^2) for Mediterranean hake (from 1996 to 2003).

Figure 8 - Spatial distribution of the Mediterranean hake mean weights (grams/individuals).

Figure 9 - Spatial distribution of biomass index (Kg/Km^2) for Deep-water rose Shrimp (from 1996 to 2003).

Figure 10 - Spatial distribution of abundance index (N/Km^2) for Deep-water rose Shrimp (from 1996 to 2003).

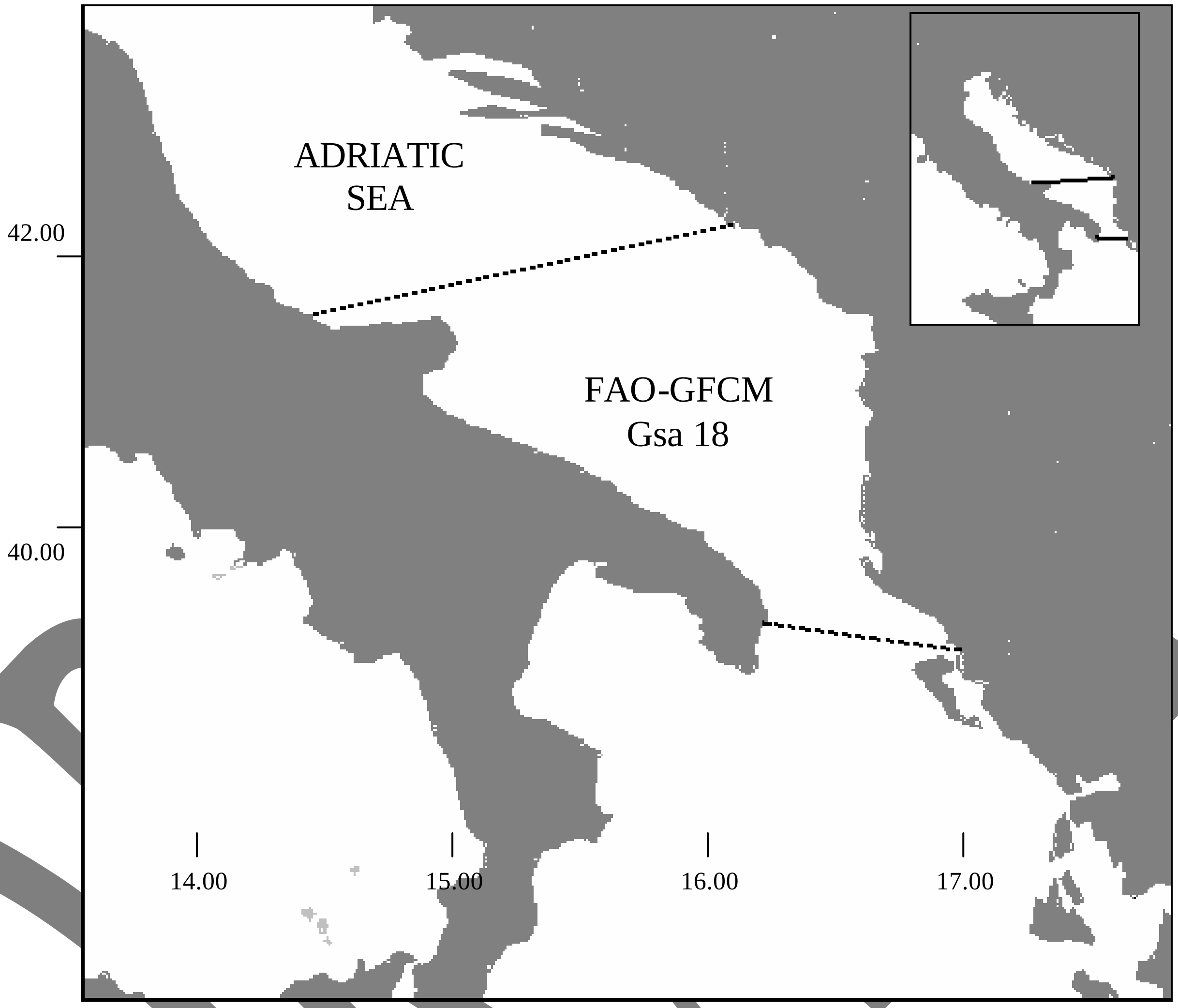

Figure 1

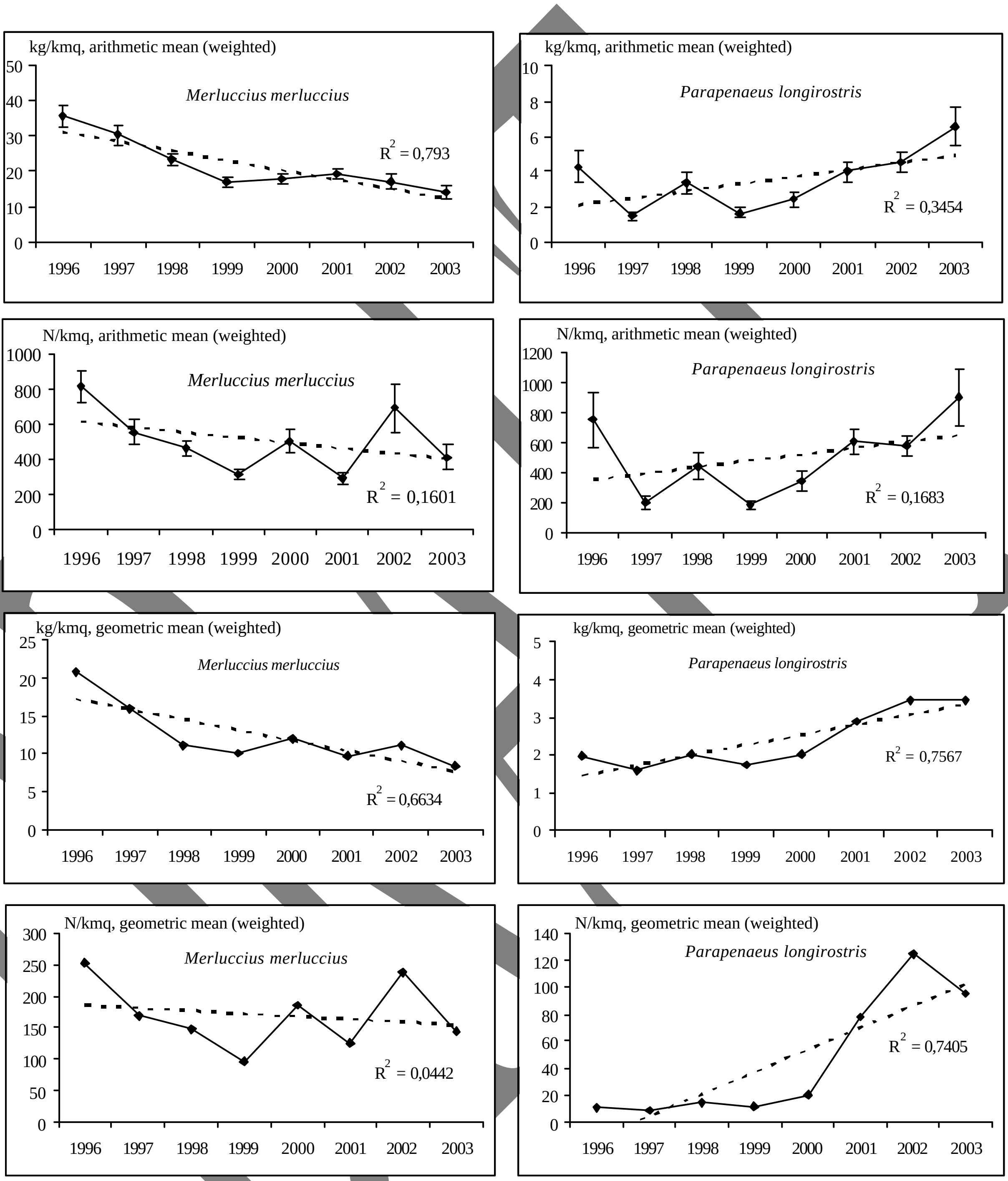
kg/kmq, arithmetic mean (weighted)
Merluccius merluccius
R² = 0,793
50
40
30
20
10
0
1996
1997
1998
1999
2000
2001
2002
2003
kg/kmq, arithmetic mean (weighted)
Parapenaeus longirostris
R² = 0,3454
10
8
6
4
2
0
1996
1997
1998
1999
2000
2001
2002
2003
N/kmq, arithmetic mean (weighted)
Merluccius merluccius
R² = 0,1601
1000
800
600
400
200
0
1996
1997
1998
1999
2000
2001
2002
2003
N/kmq, arithmetic mean (weighted)
Parapenaeus longirostris
R² = 0,1683
1200
1000
800
600
400
200
0
1996
1997
1998
1999
2000
2001
2002
2003
kg/kmq, geometric mean (weighted)
Merluccius merluccius
R² = 0,6634
25
20
15
10
5
0
1996
1997
1998
1999
2000
2001
2002
2003
kg/kmq, geometric mean (weighted)
Parapenaeus longirostris
R² = 0,7567
5
4
3
2
1
0
1996
1997
1998
1999
2000
2001
2002
2003
N/kmq, geometric mean (weighted)
Merluccius merluccius
R² = 0,0442
300
250
200
150
100
50
0
1996
1997
1998
1999
2000
2001
2002
2003
N/kmq, geometric mean (weighted)
Parapenaeus longirostris
R² = 0,7405
140
120
100
80
60
40
20
0
1996
1997
1998
1999
2000
2001
2002
2003

Figure 2

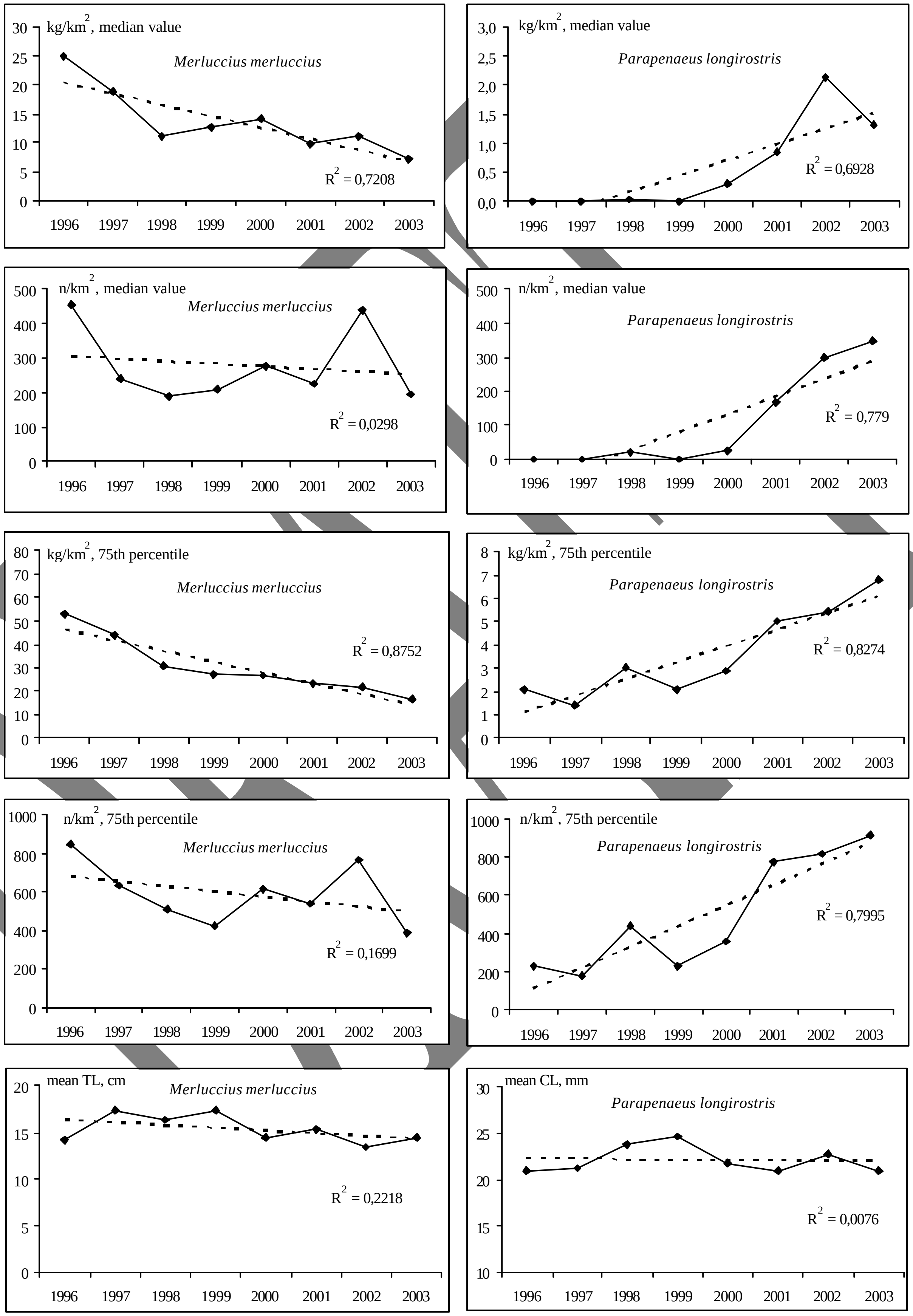
kg/km², median value
Merluccius merluccius
R² = 0,7208
30
25
20
15
10
5
0
1996
1997
1998
1999
2000
2001
2002
2003
kg/km², median value
Parapenaeus longirostris
R² = 0,6928
3,0
2,5
2,0
1,5
1,0
0,5
0,0
n/km², median value
Merluccius merluccius
R² = 0,0298
500
400
300
200
100
0
n/km², median value
Parapenaeus longirostris
R² = 0,779
kg/km², 75th percentile
Merluccius merluccius
R² = 0,8752
80
70
60
50
40
30
20
10
0
kg/km², 75th percentile
Parapenaeus longirostris
R² = 0,8274
8
7
6
5
4
3
2
1
0
n/km², 75th percentile
Merluccius merluccius
R² = 0,1699
1000
800
600
400
200
0
n/km², 75th percentile
Parapenaeus longirostris
R² = 0,7995
mean TL, cm
Merluccius merluccius
R² = 0,2218
20
15
10
5
0
mean CL, mm
Parapenaeus longirostris
R² = 0,0076
30
25
20
15
10

Figure 3

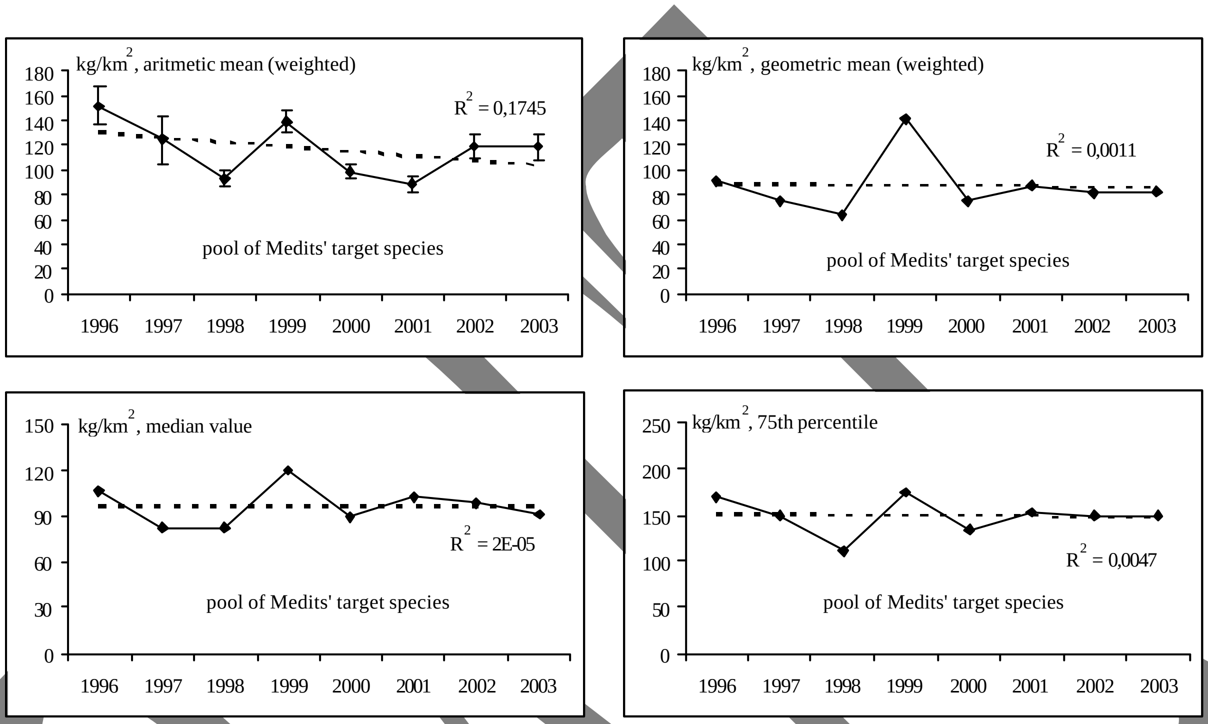
kg/km^2, aritmetic mean (weighted)
180
160
140
120
100
80
60
40
20
0
R^2 = 0,1745
pool of Medits' target species
1996
1997
1998
1999
2000
2001
2002
2003
kg/km^2, geometric mean (weighted)
180
160
140
120
100
80
60
40
20
0
R^2 = 0,0011
pool of Medits' target species
1996
1997
1998
1999
2000
2001
2002
2003
kg/km^2, median value
150
120
90
60
30
0
R^2 = 2E-05
pool of Medits' target species
1996
1997
1998
1999
2000
2001
2002
2003
kg/km^2, 75th percentile
250
200
150
100
50
0
R^2 = 0,0047
pool of Medits' target species
1996
1997
1998
1999
2000
2001
2002
2003

Figure 4

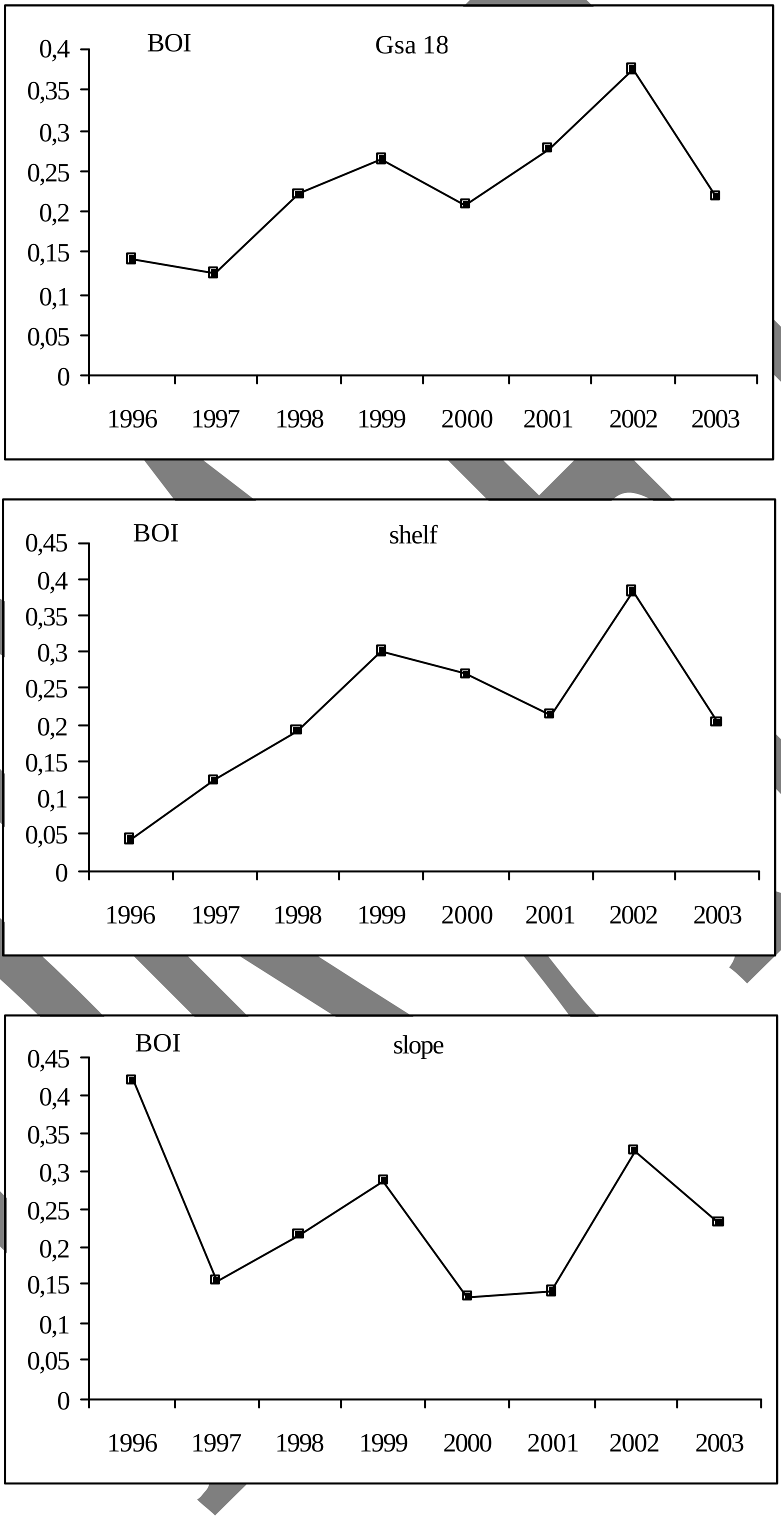
BOI
Gsa 18
0,4
0,35
0,3
0,25
0,2
0,15
0,1
0,05
0
1996
1997
1998
1999
2000
2001
2002
2003
BOI
shelf
0,45
0,4
0,35
0,3
0,25
0,2
0,15
0,1
0,05
0
1996
1997
1998
1999
2000
2001
2002
2003
BOI
slope
0,45
0,4
0,35
0,3
0,25
0,2
0,15
0,1
0,05
0
1996
1997
1998
1999
2000
2001
2002
2003

Figure 5

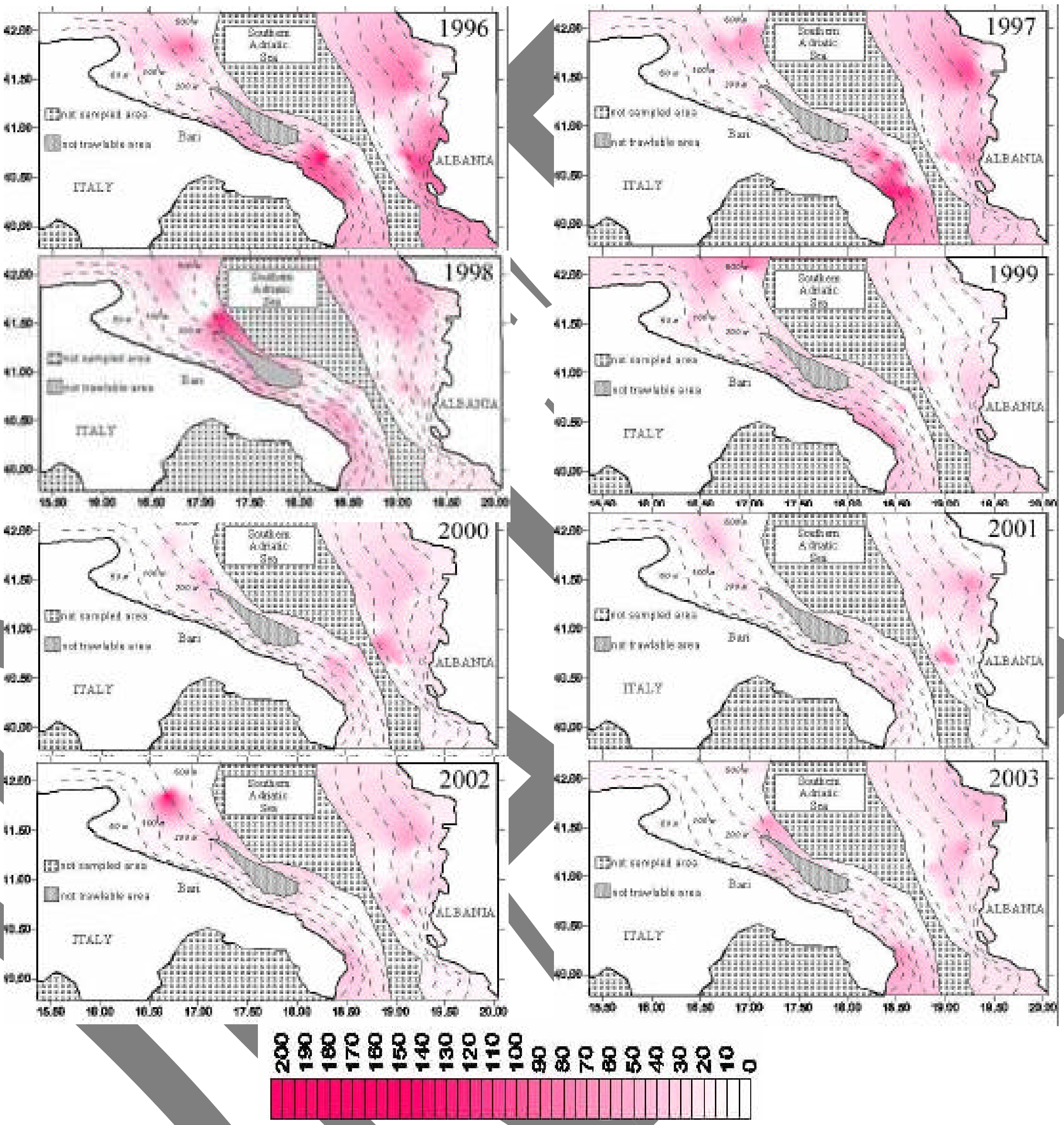
1996
1997
1998
1999
2000
2001
2002
2003
Southern Adriatic Sea
not sampled area
not trawlable area
Bari
ITALY
ALBANIA
50 m
100 m
200 m
500 m
42.00
41.50
41.00
40.50
40.00
15.50
16.00
16.50
17.00
17.50
18.00
18.50
19.00
19.50
20.00
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

Figure 6

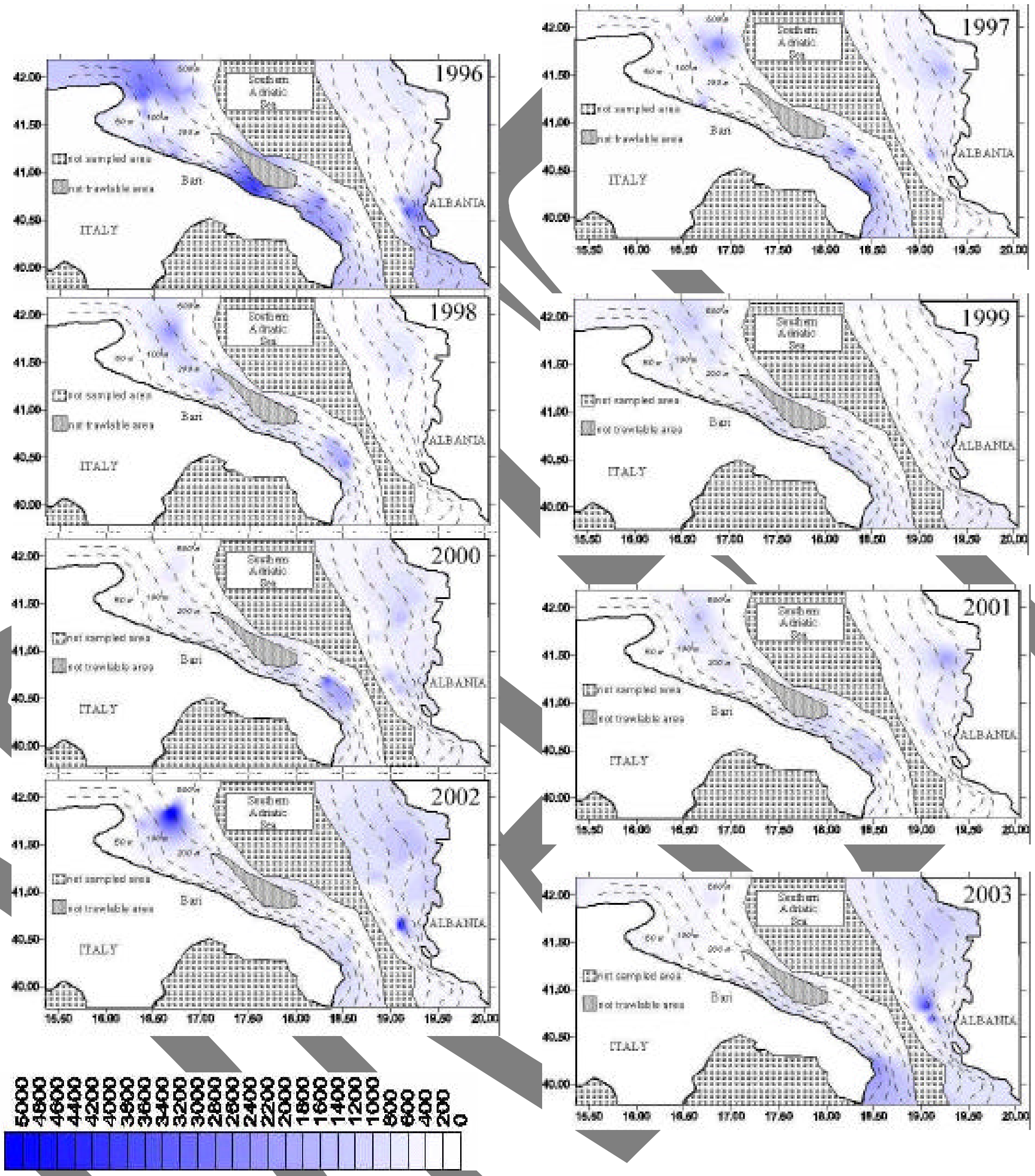
1996
1997
1998
1999
2000
2001
2002
2003
Southern Adriatic Sea
not sampled area
not trawlable area
Bari
ITALY
ALBANIA
50 m
100 m
200 m
800 m
42,00
41,50
41,00
40,50
40,00
15,50
16,00
16,50
17,00
17,50
18,00
18,50
19,00
19,50
20,00
5000
4800
4600
4400
4200
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0

Figure 7

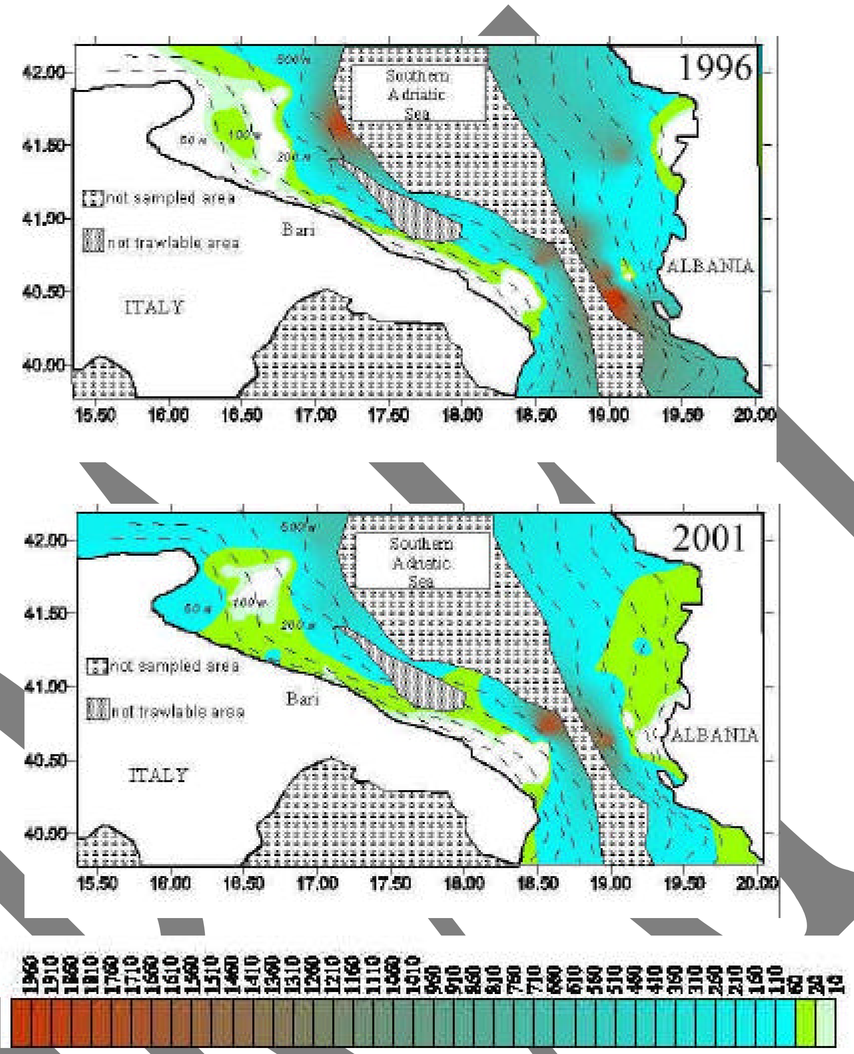
1996
2001
Southern Adriatic Sea
500 m
50 m
100 m
200 m
not sampled area
not trawlable area
Bari
ITALY
ALBANIA
42.00
41.50
41.00
40.50
40.00
15.50
16.00
16.50
17.00
17.50
18.00
18.50
19.00
19.50
20.00
1960
1910
1860
1810
1760
1710
1660
1610
1560
1510
1460
1410
1360
1310
1260
1210
1160
1110
1060
1010
960
910
860
810
760
710
660
610
560
510
460
410
360
310
260
210
160
110
60
24
10

Figure 8

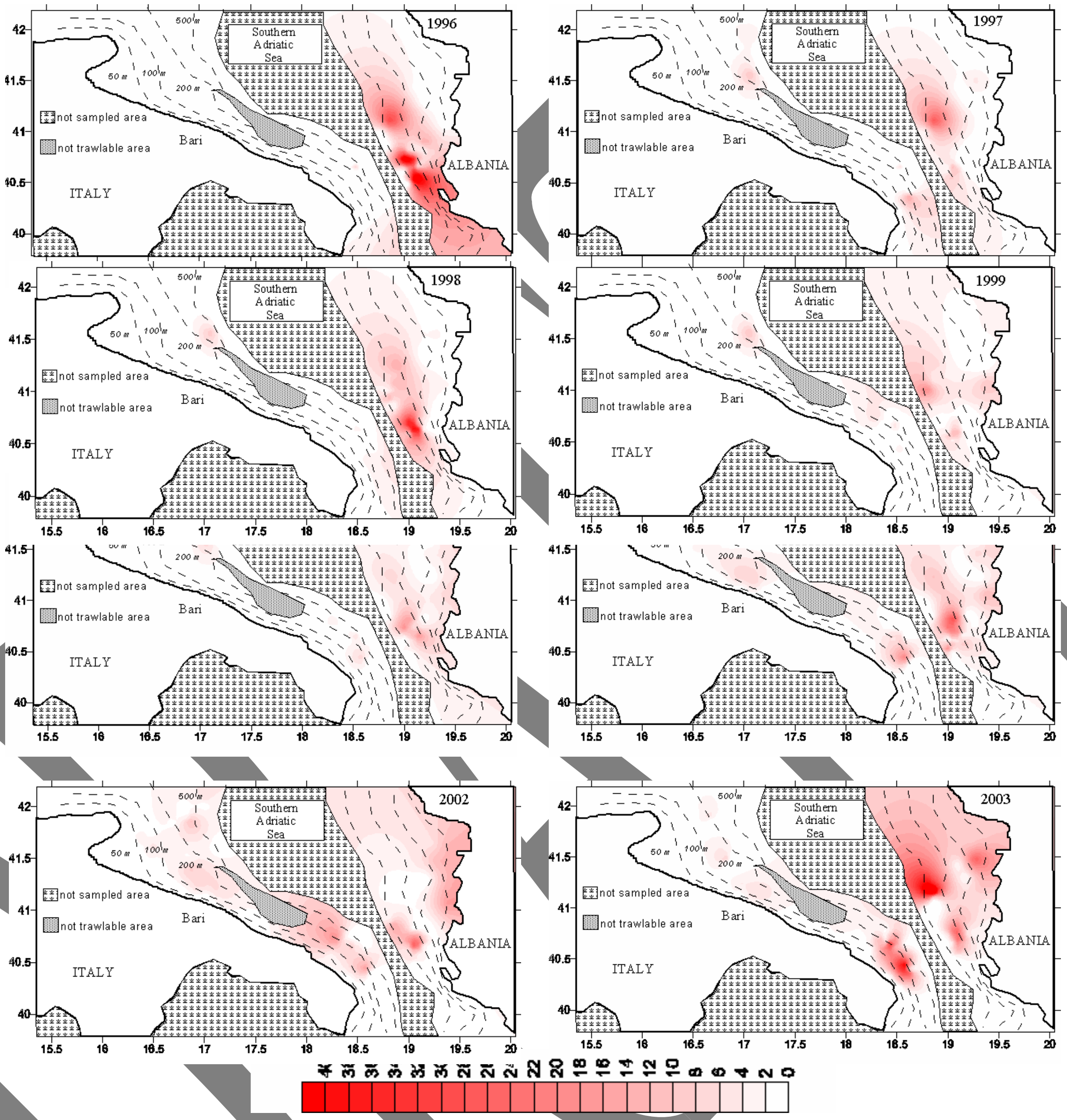
1996
1997
1998
1999
2002
2003
Southern Adriatic Sea
ITALY
ALBANIA
Bari
not sampled area
not trawlable area
50 m
100 m
200 m
500 m
42
41.5
41
40.5
40
15.5
16
16.5
17
17.5
18
18.5
19
19.5
20
22
20
18
16
14
12
10
8
6
4
2
0

Figure 9

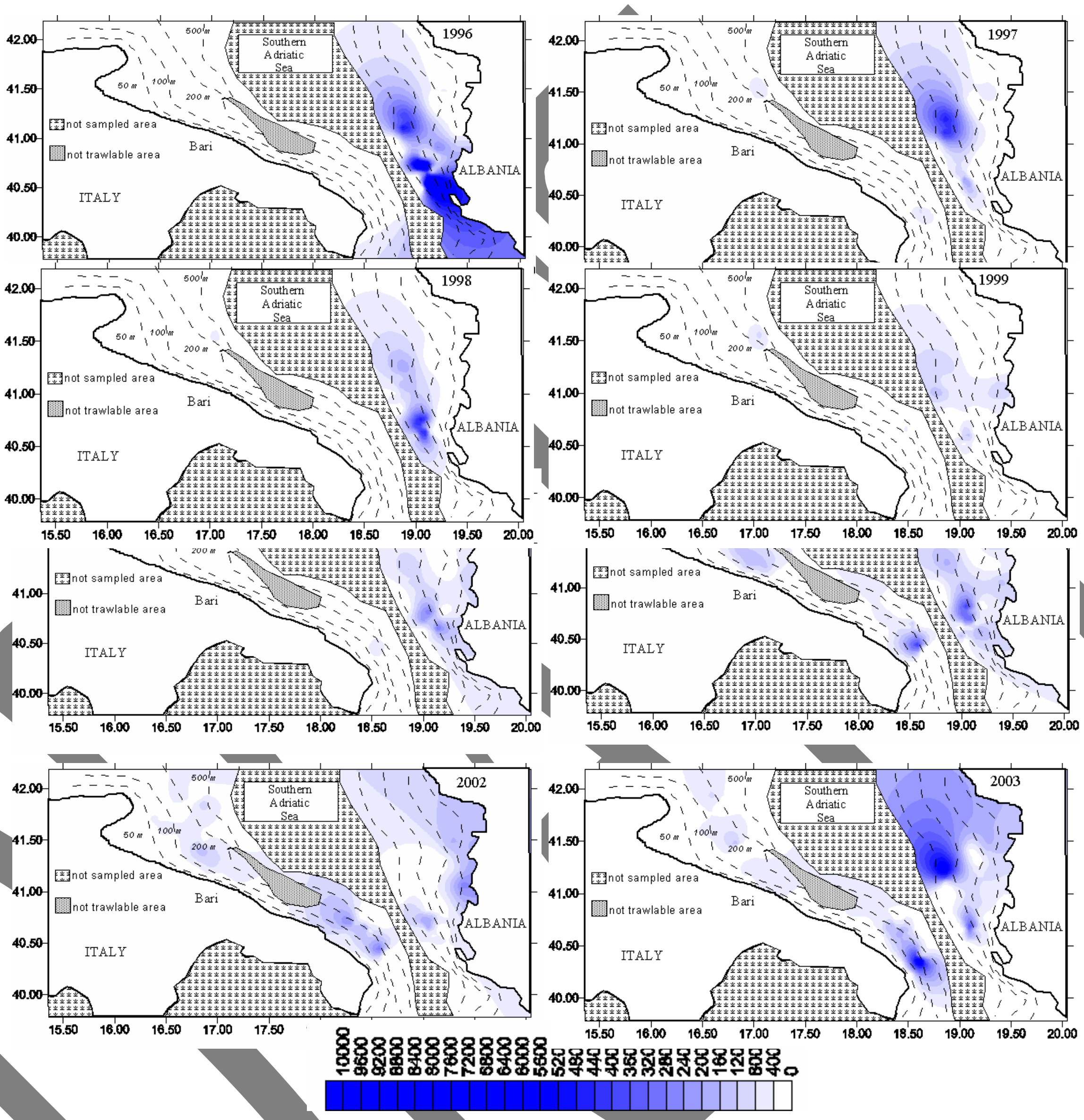
1996
1997
1998
1999
2002
2003
Southern Adriatic Sea
not sampled area
not trawlable area
Bari
ITALY
ALBANIA
50 m
100 m
200 m
500 m
42.00
41.50
41.00
40.50
40.00
15.50
16.00
16.50
17.00
17.50
18.00
18.50
19.00
19.50
20.00
10000
9600
9200
8800
8400
8000
7600
7200
6800
6400
6000
5600
520
480
440
400
360
320
280
240
200
160
120
80
40
0

Figure 10

INTERVENTION OF THE FISHERIES CO-OPERATIVE ASSOCIATIONS

AGCI Pesca- Federcoopesca- Lega Pesca

The Co-operative Associations of the fishing sector in Italy express their warm thanks to the organisation of this workshop and to the Consorzio UNIMAR, accepting the invitation of the General Directorate of Fisheries and Aquaculture with this short contribute.

This workshop follows the seminar of the past 28th-29th January, organised by UNIMAR and SIBM on behalf of the Italian Ministry of Agriculture and Forestry Policy, in which different communications have already underlined the complexity related to the identification of Reference Points for natural resources evaluation.

At the same time, from management point of view, it has been underlined the extreme difficulty to connect these analyses to the reality of the fisheries system in the Mediterranean basin, which is characterised by a strong multispecificity of catches.

The Associations believe that the participating approach to the processes of decision is a fundamental assumption for the success of the resources' management, and it is necessary that the technical measures can be understood by the different actors of the fishing sector.

It is not by chance that the Associations have acquired the principles expressed in the FAO "Code of conduct for responsible and sustainable fisheries", by conceiving advisory materials and by spreading them in a wide and capillary way. The same Research Institutes of the co-operative movement (CIRSPE, Consorzio Mediterraneo, ICR Mare and the Consorzio UNIMAR) have realised initiatives, in which the information material (films, CD-ROMs, papers) has created a technical support for meetings and workshops with fishermen.

The fisheries Association remark the importance of the assumption to link catch to resource conditions but, often, the "aseptic" application of quantitative models risk becoming a pure and simple algebraic exercise, far from a fishing activity sustainable from social and economic point of view; a the strong reduction of the fishing effort cannot be proposed without considering the social and economic impacts.

The management of resources cannot put aside the evaluation of the effects on the fishermen community, especially in a situation such as the Mediterranean one, in which the "employment" factor is prevailing on the "income" factor.

Therefore, there is the need to characterise clear RPs for the definition of the state of the resource, thus allowing the Public Administrations to identify effective management measures for the different productive realities.

This need is emphasised by the geopolitical contest in the Mediterranean, where there are different approaches to the resources exploitation and where the resources are often shared by different Countries.

Too often, the models used for the study of the dynamics of stocks, follow the experiences conducted in other geographical areas where they have led to results which are anything but satisfactory. Therefore, there is the need to define reference indexes strongly adherent to the specific features of the Mediterranean fishery.

At the same time, it is important to remark that one of the main objectives of the Fishery Policy must be to connect the natural resource protection with the economic context.

In other words, it will be necessary to evaluate the effects of the application of management models on the fishery sector, in order to avoid negative impacts from social point of view, taking also into account the market and the different employment opportunities in the coastal area,

Thank you for your attention.