Ministero delle Politiche Agricole e Forestali

General Fisheries Commission for the Mediterranean– Scientific Advisory Committee (GFCM-SAC)

Organized by:

Workshop

Identification of Reference Points for the management of fishery resources

20 - 21 April 2004

Palazzo Altemps
Via De' Gigli d'Oro, 21 - Roma

Technical document

Motivations

The need to identify Reference Points for the Mediterranean arises from the need to build a monitoring system of the state of fishing resources based on homogeneous indicators in keeping with the reality of the Mediterranean.

In particular, today this need is even more pressing for at least four reasons:

1. The European Union, together with the national governments, has started a complex data gathering system (regulations 1543/00 and 1639/2001), with the goal of setting up a common data base for all the European countries in the Mediterranean basin.
2. The precautionary approach to fishing management (FAO, 1996) points to the need to identify conservative reference points whose sole goal is not only to maximize yield-per-recruit ($\mathbf{F_{max}}$) or production (**MSY**).
3. We now have a consistent series of data from trawl surveys (GRUND and MEDITS programs) that should be properly used to provide steady management information to government offices.
4. The experiences outside of the Mediterranean have highlighted some clamorous failures in stock assessment and/or management. In this context, there has been an increased need to make use of efficient, effective indicators.

The general context

The Reference Points (**RP**) were developed conceptually in fishing areas managed with "adaptive" criteria (ICES, NAFO, ICCAT, etc…) to deal with the more or less serious problem of overfishing affecting most world stocks. They represent a set of empirical or theoretical indicators on the state of resources and, more recently, on the environment where these resources reside, closely tying the problems of assessment to those of management. They can be divided into two basic groups that have very different meanings:

- Limit Reference Points (**LRP**) are the threshold beyond which there is a high chance of compromising the stock's ability to replenish itself; inevitably linked to the biological characteristics of the species exploited and the environment where they live.
- Target Reference Points (**TRP**) are the average value of a stock indicator, compatible with precautionary management goals.

Further specification of the RP is the identification of the so-called buffer zones that identify an area between the LRP and the TRP where management goals and danger indicators are classified.

The Mediterranean context

The existence of biological and technological interactions is of particular importance in "mixed fishery" situations like that of the Mediterranean. In that type of context, the definition of "optimal harvesting" should refer to the entire ecosystem or, in any event, to a multi-specific setting, e.g. size spectra for groups of fauna, biodiversity indicators, fish assemblage composition, k-dominance of density and biomass, etc.

However, even though of great importance for the coming future, the present lack of data and specific information makes it extremely difficult in the short- to medium-term, to identify and test appropriate Biological Reference Point (**BRP**) according to the so-called ecosystem approach.

A relatively simply way of transforming scientific indicators into management indicators is to monitor the variations in abundance by species or groups of species, together with variations on the composition by size and/or age of the various species. This is possible through surveys, conducted with a standardized fishing gear, repeated with appropriate frequency and density to a level preset of estimate precision. While that kind of approach is of chiefly a qualitative nature, it would have the advantage of simplicity, as well as being easily explained and understandable for system users and managers.

In the Italian Mediterranean seas, preference has been given to approaches based on analytic or production models using trawl survey data (e.g. composite production model), due to the lack of consistent data series on commercial fishing.

At the level of single species, the total instanteous death rate (Z), that can be calculated from trawl survey data and related to the fishing mortality rate, is, together with other possible indicators, one of the most promising. In this regard, some of the recently proposed BRP are as follows:

- **Z*,** a simple indicators of age/length of the sea population compatible with, in average, a reproductive event during the life of a cohort, proposed by Die and Caddy (1997) and used by Zamboni *et al*. (1999).
- $\mathbf{Z_{MBP}}$, based on a composite production model, as per Csirke and Caddy (1983), and used by Abella *et al*. (1999).
- $\mathbf{Z_{med}}$, an indicator of the total mortality rate compatible with a stock recruitment rate, proposed by Zamboni *et al*. (2000), similar to BRP originally developed by the ICES, keeping fish mortality in mind. This approach is based on knowledge of stock-recruitment ratios.

With reference to reproduction and the need to identify conditions of "recruitment overfishing", the ratio-based BRP is equally promising, and enough to guarantee self-renewal of the population, with the broodstock biomass and that potentially present in the case of virgin stock **(%SSB)**.

Like the examples given above and including the concept of spatial variability, BRP hypotheses were formulated through assessment of fishing effort intensity (for instance TSL or Hp/square mile) for the different areas analyzed in relation to the state of population and fish community structure (Ardizzone *et al.*, 1998).

Along with the BRP, essentially characterized by a biological matrix, there are RP with a bio-technological matrix based on the relation between the present fishing effort and that considered optimal (e.g. MOSES of IREPA). They are mainly based on application of bio-economic optimization models of fishing. Other economic RP are based on short- and medium-term optimal performance values. They measure the sustainability of economic activity in relation to the state of biomass stocks. The latter are derived by the economic reports of various fishing sectors and, as such, combine biological and economic prospects.

Bibliography

Abella, A., Belluscio A., Bertrand J., Carbonara P.L., Giordano D., Sbrana M., Zamboni A., 1999. Use of MEDITS trawl survey data and commercial fleet information for the assessment of some Mediterranean demersal resources. *Aquat. Living Resour*. 12 (3):155-166

Ardizzone G.D., Agnesi S., Biagi F., Baino R., Corsi F., 1998. Geographical Information System and Surplus Production Models: a new model for spatial assessment of demersal resources. IFREMER *Actes de Colloques* (26):97:111

Csirke J., Caddy J.F., 1983. Production modelling using mortality estimates. Can. J. Aquat. Sci., 40: 43- 51.

Die D. J., Caddy J. F., 1997. Sustainable yield indicators from biomass: are appropriate reference points for use in tropical fisheries? Fish. Res. 32 :69-79.

FAO, 1996. Precautionary approach to fisheries. Part 1. Guidelines on the precautionary approach to capture fisheries and species introduction. FAO Fish. Rep., 350/1: 1-52

Zamboni A., Rossi M., Fiorentino F., 1999. “L’impiego della mortalità totale per valutare la sostenibilità dello sfruttamento di Mullus barbatus” (L., 1758) (Osteichthyes - Mullidae) lungo la costa Ligure. Biol. Mar. Medit. 6 (1): 630 - 634.

Zamboni A., Rossi M., Mannini A., Gatto A., Fiorentino F., 2000. La capacità di rinnovo della triglia di fango Mullus barbatu”s (L., 1758) in Mar Ligure sulla base della relazione adulti/reclute. Biol. Mar. Medit. 7 (1): 107-116.

Program of the Workshop

April 20

10,00-10,30 **opening the meeting**

Italian Directorate for Fisheries
General Fishery Commission for the Mediterranean
Scientific Advisory Committee
Sub-Committee Stock Assessment
Società Italiana di Biologia Marina

10,30 **Piccinetti C.**
Laboratorio di Biologia Marina e Pesca, Università di Bologna – Fano (PS), Italy
Reference points: a new approach to manage the Italian fishery.

10,30 **J.F. Caddy**
Consultant to the Black Sea Commission - Istanbul, Turkey
The potential use of indicators, reference points and the traffic light convention for managing Black Sea fisheries.

11,30-11,50 **coffee-break**

11,50 **Ferrandis E., Lloris D., Hernandez P., Campo M., de Sola L.G.**
Dto. De Estadisatica - Universidad de Alicante
Recruitment Trends based on Trawl Survey Data. Analysis of their Robustness.

12,20 **[1]Spedicato M.T., [1]Carbonara P., [2]Rinelli P., [1]Silecchia T., [1]Lembo G.**
[1]Coispa Tecnologia & Ricerca, Stazione Sperimentale per lo Studio delle Risorse del Mare - Bari, Italy;
[2]IAMC-CNR Sezione di Messina, Italy
Simulation of different management scenarios based on the spawning stock biomass level. The case of red mullet (*Mullus barbatus* L., 1758).

13,00-14,30 **lunch**

14,30 **[1]Ungaro N., [1]Ceriola L., [1]Marano C.A., [2]Osmani K., [3]Mannini P.**
[1]Laboratorio Provinciale di Biologia Marina - Bari, Italy;
[2]Fisheries Research Institute - Durres, Albania;
[3]FAO-AdriaMed Project - Termoli, Italy.
On the suitability of some indicators from trawl surveys data. Mediterranean geographical sub-area 18.

15,00 **Lleonart J.**
FAO
Indicators and reference points provided by the VIT software.

15,30 **Lleonart J., J. & F. Maynou**
FAO
The application of Composite Production Models with survey biomass indices.

16,00 **F. Maynou & J. Lleonart**
FAO
Searching for multispecies indicators based on diversity measures.

16,30-16,40 **coffee-break**

16,40 **Sabatini A., D. Cuccu, M. Murenu, M.C. Follesa, A. Cau**
DBAE - Università di Cagliari, Italy
Application of Biological Reference Points: analysis of three different levels of *Aristaeomorpha foliacea* exploitation.

17,10 **Levi D.**
IRMA-CNR Mazara del Vallo (TP), Italy
Turnazione e premio: due strumenti congiunti per tornare ad una pesca sostenibile (Twin tools to get back to sustainable fishing: shifting + prize awarding).

17,40 **G. Palandri, F. Garibaldi, C. Cima, L. Lanteri, L. Orsi Relini**
Dip.Te.Ris., Laboratorio di Biologia Marina ed Ecologia Animale, Università di Genova, Italy
Looking for reference points for the Mediterranean swordfish fishery.

18,10 **[1]Abella A., [2]Carpentieri P., [3]Mannini A., [4]Sartor P., [4]Viva C., [1]Voliani A.**
[1]Agenzia Regionale Protezione Ambiente Toscana, Sez. GEA - Livorno, Italy
[2]Dipartimento di Biologia Animale e dell'Uomo, Università di Roma, Italy
[3]Istituto di Zoologia, Università di Genova, Italy
[4]Centro Interuniversitario di Biologia Marina (CIBM) - Livorno, Italy
Selection of possible indicators of sustainable yield from total mortality rates for *Mullus barbatus* in the GFCM Geographic Sub-Area 9.

April 21

09,30 Contribution of Italian fishery cooperatives Associations

10,00 **Gramolini R., C. Manfredi., Piccinetti, C.**
Laboratorio di Biologia Marina e Pesca, Università di Bologna – Fano (PS), Italy
Identification of reference points for the Northern and Central Adriatic demersal stocks.

10,30 **Ticina *et al*.**
Institute of Oceanography and Fisheries - Split, Croatia
Acoustic estimates of small pelagic fish stocks in the eastern part of Adriatic Sea.

11,00 **[1]Ragonese S., [1]Bianchini M.L., [2]Camilleri M., [1]De Santi A., [1]Fiorentino F., [1]Gristina M., [1]Garofalo G., [1]Morizzo G.**
[1]MaLiRA-Group, Ist. Risorse Marine e Ambiente (IRMA), sez. IAMC/CNR, Mazara del Vallo (TP), Italy
[2]Malta Centre for Fisheries Sciences (MCFS), DFA-MAF, Malta.
Toward the establishment of reference points to manage the fisheries in the strait of Sicily.

11,30-11,50 **coffee-break**

11,50 **Santojanni A., N. Cingolani, E. Arneri, A. Belardinelli, G. Giannetti, S. Colella, F. Donato**
CNR-ISMAR, Sezione Pesca Marittima - Ancona, Italy
Use of an exploitation rate threshold in the management of anchovy and sardine stocks in the Adriatic Sea.

12,20 **Ferrandis E., D. Lloris, P. Hernández, M. Campo, L. Gil de Sola**
Dto. De Estadisatica - Universidad de Alicante
Reference Points based on Survival Analysis: Mortality Rates (Natural, Total, Fishing), Exploitation Rate, Life Expectancy and Median Survival Time. Comparison of their Robustness using Real and Simulated Data.

12,50 **[1]Tudela S., [2]Coll M., [2]Palomera I.**
[1]WWF Mediterranean Programme - Barcelona, Spain.
[2]Institut de Ciències del Mar (CSIC) - Barcelona, Spain.
Developing an operational reference framework for fisheries management based on the composite indicator $PPR\text{-}TL_{catch}$.

13,20-15,00 **lunch**

15,00-17,30 **Discussion and conclusions**

Each communication will last 20 minutes + 10 minutes for discussion

REFERENCE POINTS: A NEW APPROACH TO MANAGE THE ITALIAN FISHERY

PICCINETTI C.

Laboratorio di Biologia Marina e Pesca dell’Università di Bologna,
V.le Adriatico 1/n, 61032 Fano (PS), Italy

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 methods used for the determination of the state of stocks, of the rules adopted to manage the fishery, of 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
- assumption for models not verified
- monospecific approach
- low consideration of basic principles of ecology, for i.e. prey predators, mortality density dependent, variability of recruitment etc.
- fishing effort estimated with large imprecision
- fishermen and public opinion difficulties to understand the workers language in fishery science
- low confidence of fishermen in the advice of scientist and international commission, without practical confirmation
- long time is necessary from advice to implementation of protection measures
- oppositions of the fishermen to observe measures without fishermen 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 stock state and fishery, easy to understand for fishermen and realistic, i.e. quantity of fish at sea, global index and species index, the spawners index, economic income of a standard catch of a vessel, etc.
2) It is necessary to establish a limit value for each indicator, reference points: the fishery continues without new rules over the limit value, a situation of attention starts under the 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) A monitoring plan starts in collaboration with the fishermen organisations when limit value for attention 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 referent point will be reached.
6) The measure are graduated in relation to importance of alarm limit. 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 alarm reference point will be exceeded.

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

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

J.F.CADDY (*)

Consultant to the Black Sea Commission
Istanbul, Turkey
(*) jfcaddy@yahoo.co.uk

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.

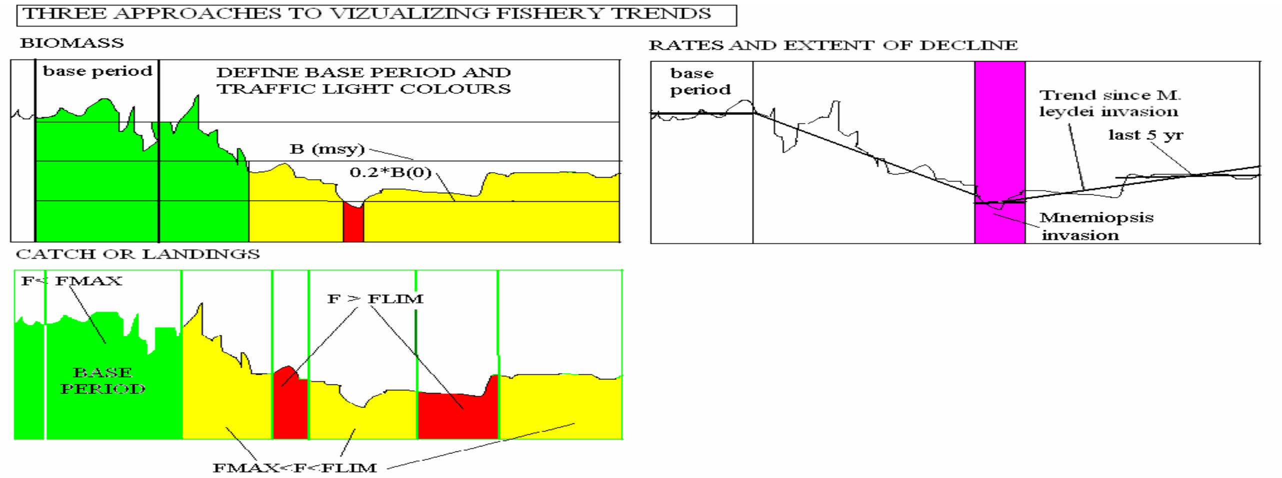


Fig 1: Potential uses of indicator series for analysing changes in Black Sea fishery resources. (Top left): biomass levels expressed in traffic light colouration for two RP levels; B(MSY) and $0.2*B_0$. (Bottom left): Landing trends coloured using annual estimates of fishing mortality based on retrospective 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 M. leydei invasion.

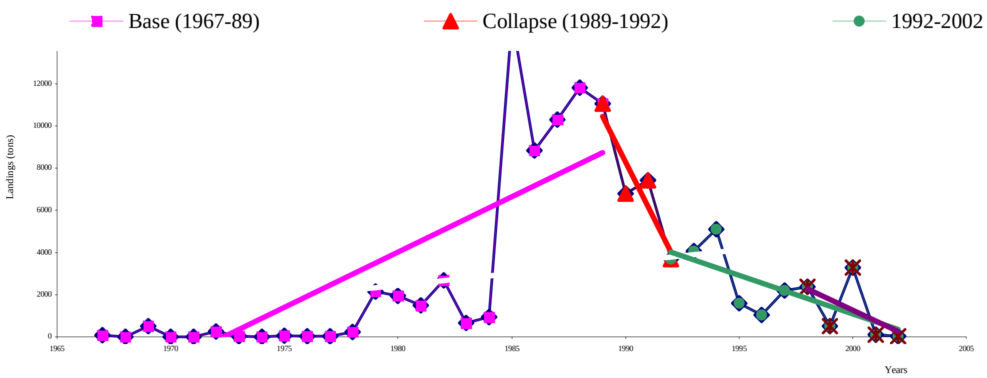
Use of trend analysis and the extent of decline in landings

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

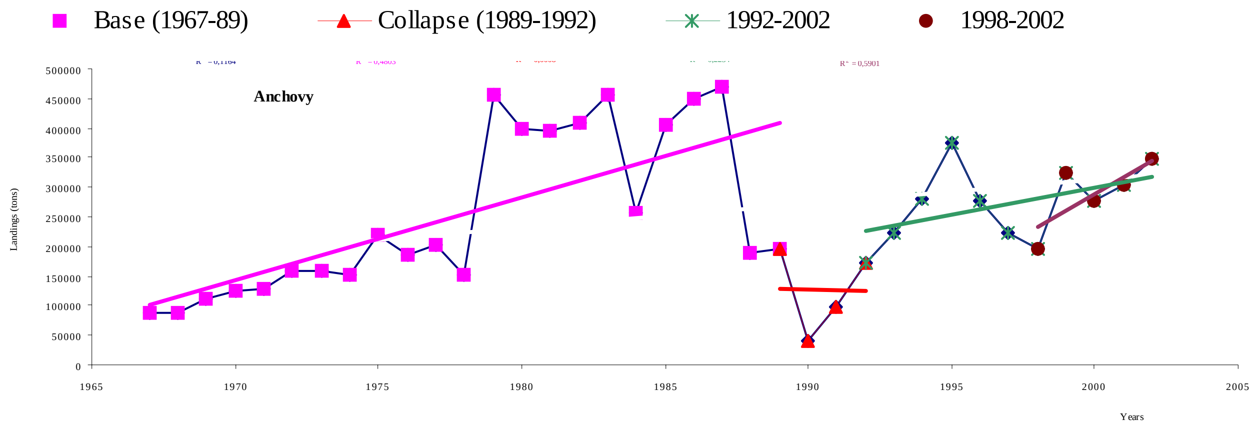


Fig 2: Segmentation of catch trends for a migratory and resident pelagic species, in light of the Mnemiopsis invasion, showing similarities and differences.

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. leydei*.	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 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	Recruitment of small pelagics is	Recruitment of small pelagics in the Black

(1999)	less dependent on parental stock size than environment variables (e.g. wind stress).	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.

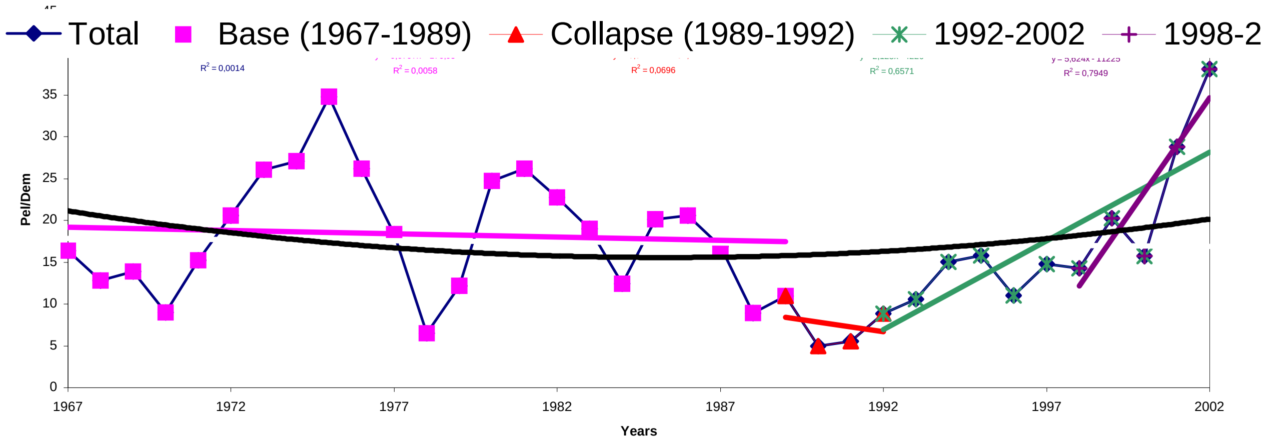
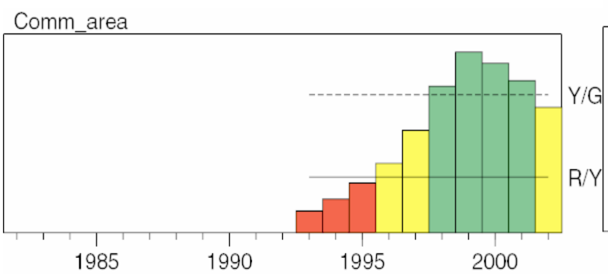


Fig 3: The pelagic/demersal index for Black Sea catches, and a polynomial fit for the whole time series, suggesting a decline to low levels in the 1980's, and some subsequent recovery after 1992.

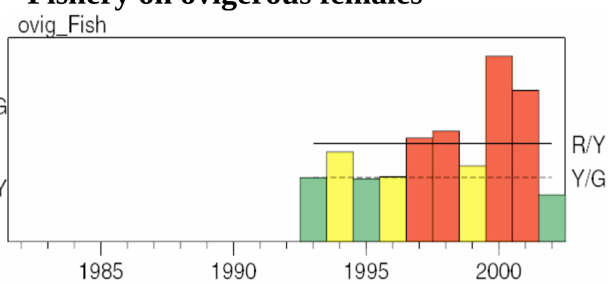
Displaying multiple indicators – the traffic light approach

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



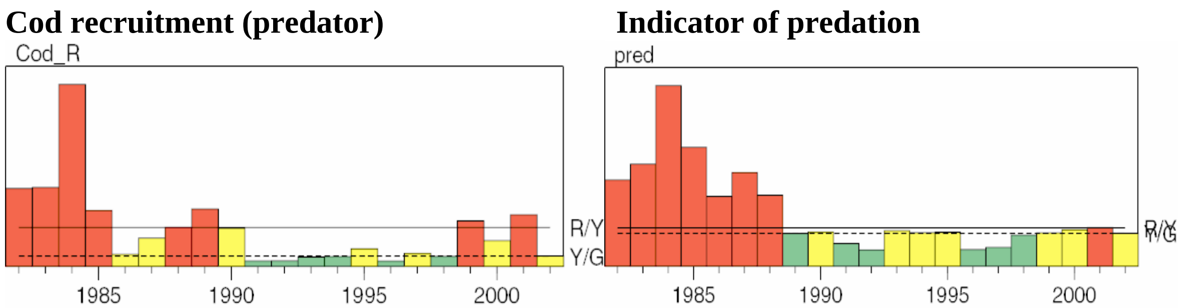


Fig 4: Extracts from a traffic light monitoring report for Northern shrimp (Pandalus borealis) by Koeller et al. (2000) shows 4 indicator series, segmented at the green-yellow and yellow-red boundary by biological criteria agreed to between resource experts and the fishing industry.

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).

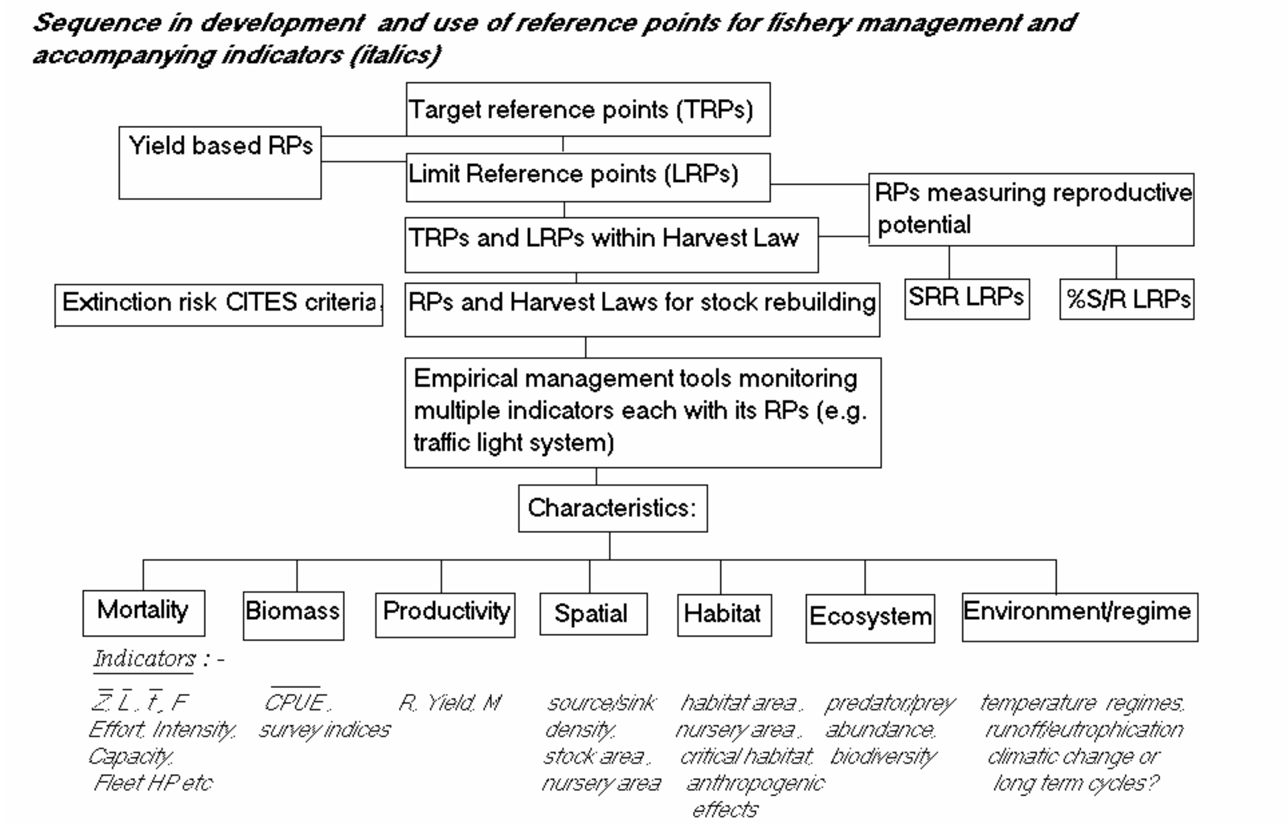


Fig 5: Evolution in the use of reference points (top downwards). Reference points based on MSY as a target were specified in the Law off the Sea, but in the 1990's emphasis moved to model-based LRP's, especially based on spawning potential, as marking limits when management action is

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.

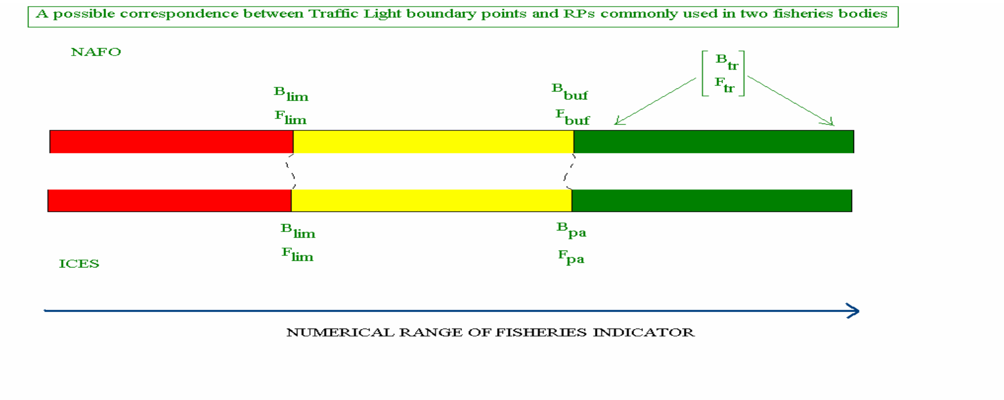
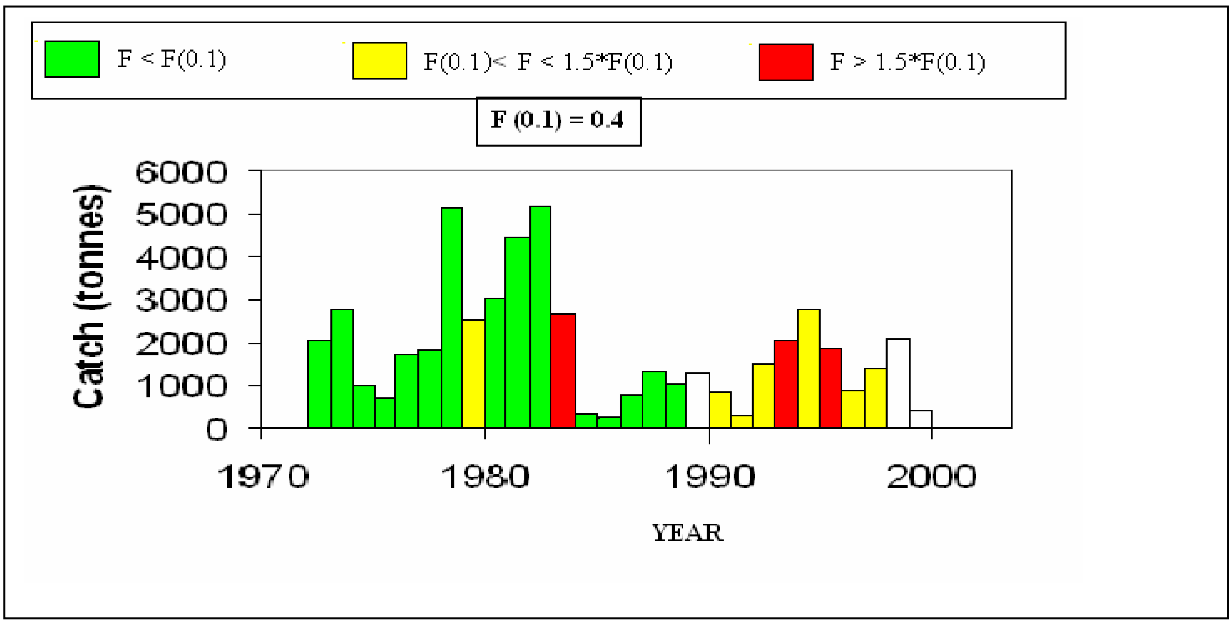


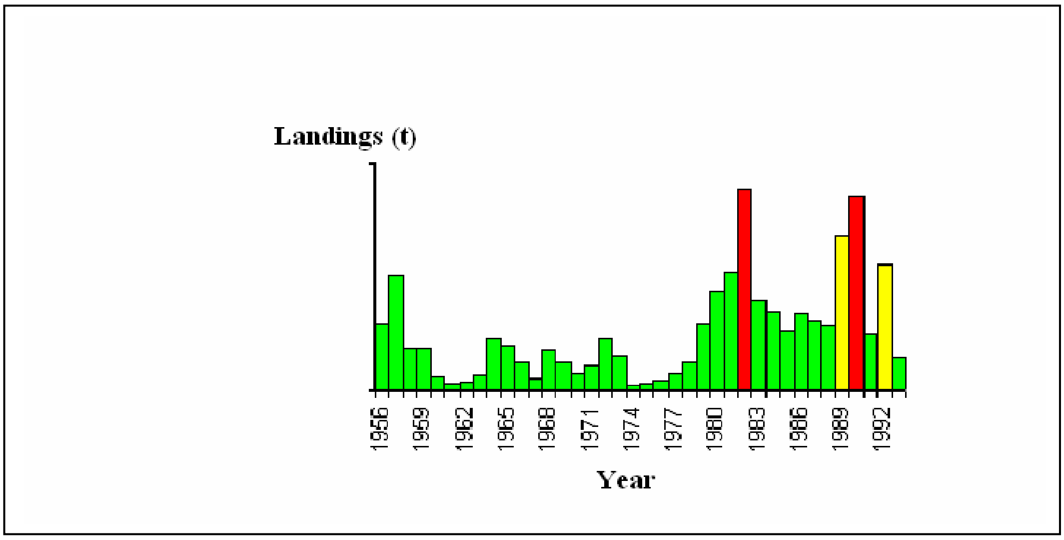
Fig 6: Illustrating how the colour convention used in traffic light colour charts can be reconciled with the precautionary and limit reference point criteria used in ICES and NAFO.

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.

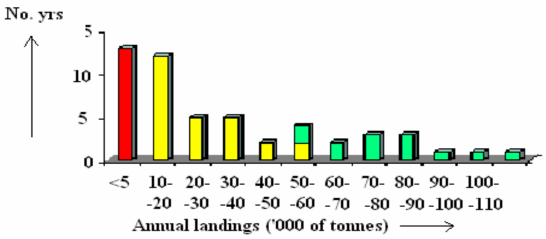


Fig 8. Dividing a time series into three colour categories (sprat landings) – Note: 'red' in this case does not represent uniformly unfavourable conditions, as the initial years of the fishery when effort is low are also classified as 'red'.

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.

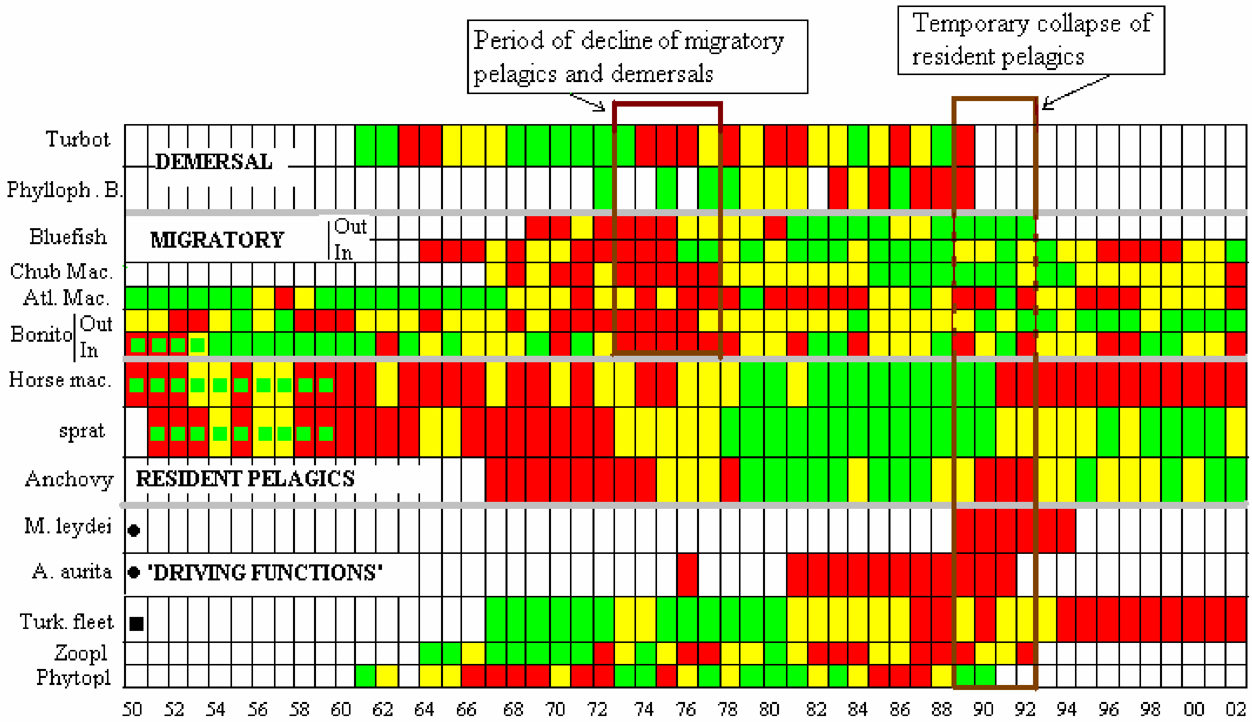


Fig 9: Traffic light illustration of trends in multiple indicators using the procedure in Fig 8. For commercial species, indicators are landings, but a low 'red' value in the 1950's probably does mean overexploitation, and early pelagic catches are stamped with a green square. 'Red' may be associated 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:

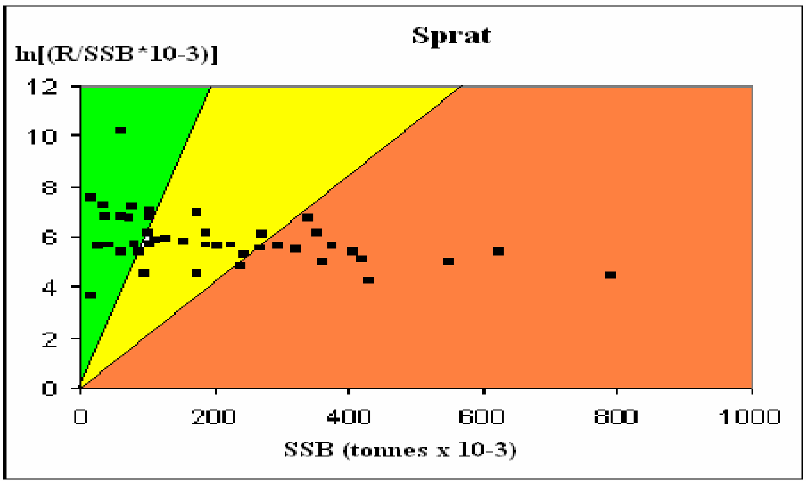
1) Phytoplankton standing crop in the 1960s to early 70s was relatively low, but rose in the 1970's-80's presumably due to eutrophic effects associated with hypoxia of Black Sea shelves (Zaitsev 1993). Landings of 'resident' pelagics (anchovy, sprat and horse mackerel) increased in the 1980's and planktonic 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.



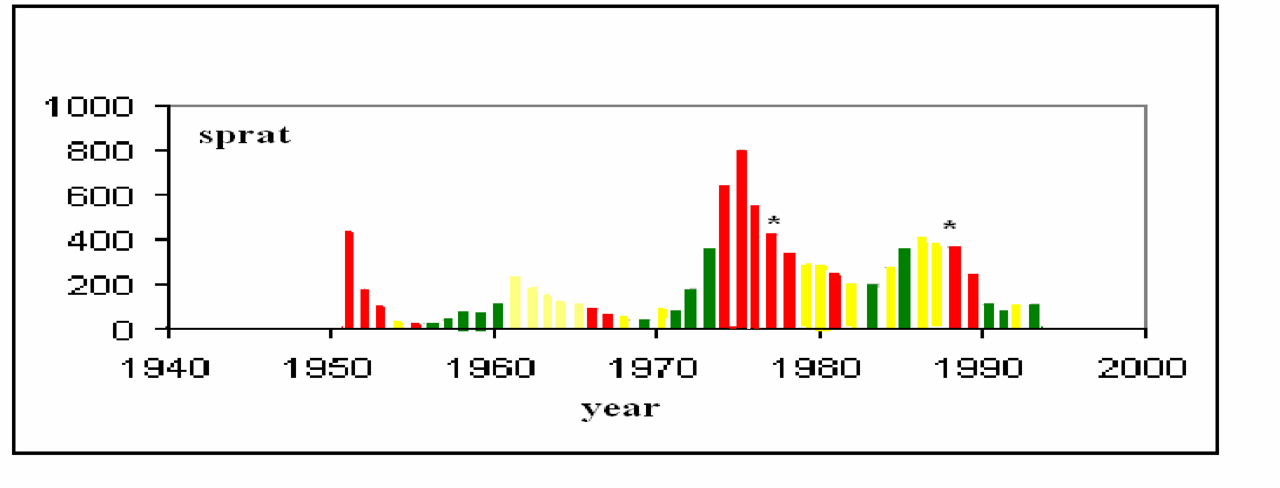


Fig 10: (<u>Upper</u>) Segmenting SSR data for Black Sea sprat into three zones with equal numbers of points per zone. (<u>Lower</u>) Time sequence of sprat biomasses show resulting low, medium and high levels of recruitment success by red, yellow and green respectively. The two asterisks mark periods when jellyfish (first <u>Aurelia</u> then <u>Mnemiopsis</u>) 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)

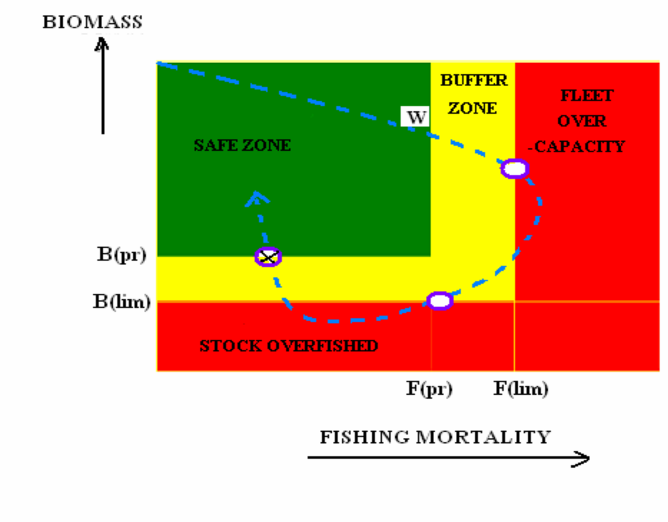


Fig 11: Visualization of a fisheries control law such as the Magnuson-Stevens Act of the US Congress in traffic light terms. Here, precautionary reference points for biomass (B) and fishing rate or capacity (F), mark the transition from safe (green) to uncertain (yellow) conditions, and limit reference 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).

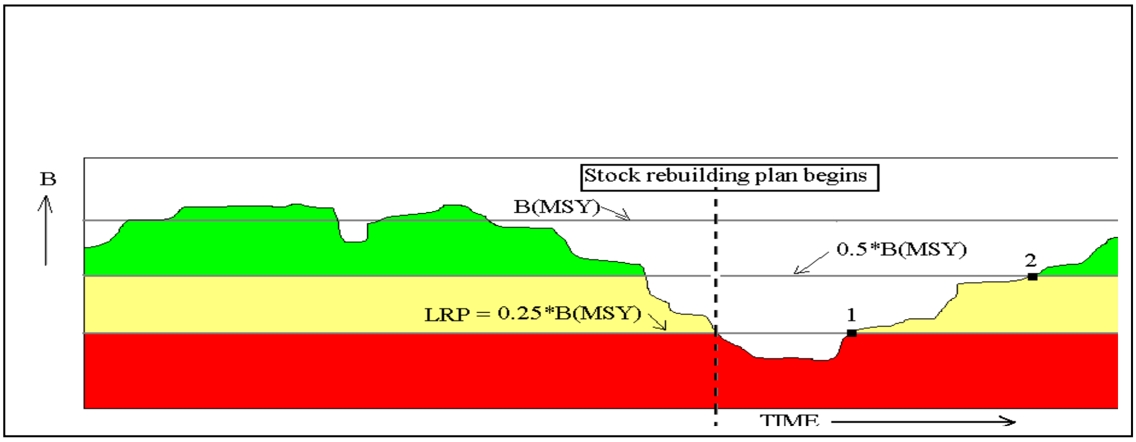
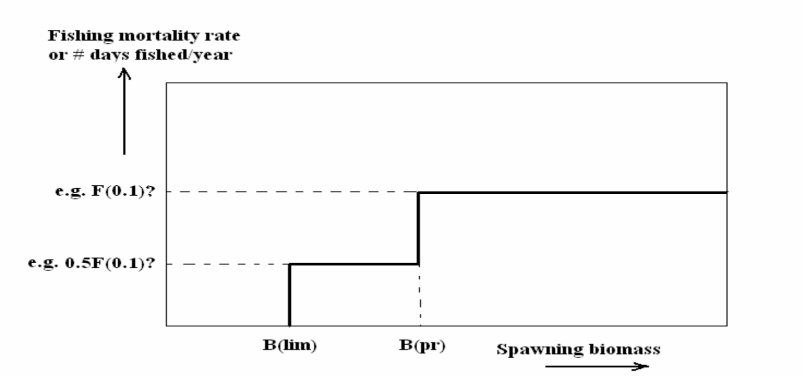


Fig 12: Possible use of a management rule for stock rebuilding. The biomass corresponding to a quarter of that needed to support extraction of MSY, initiates a compulsory recovery plan which continues until the biomass is once again above B(MSY). (Points 1, 2 and 3 are 'way stations' serving to identify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



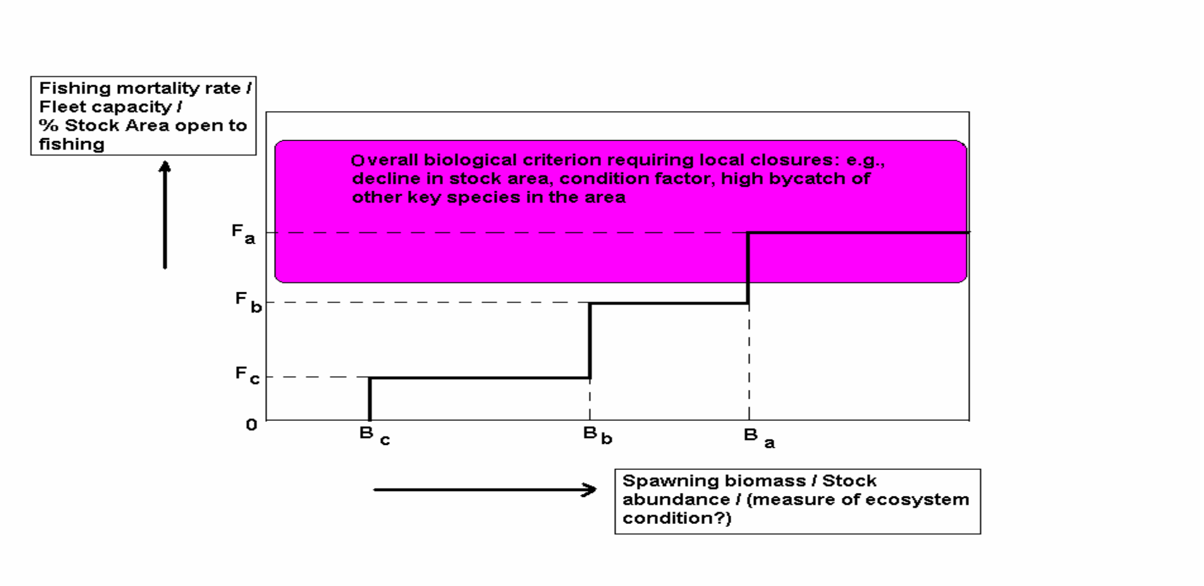


Fig 13: Two types of management rule. Upper: A simple management rule constrains fishing mortality at B_{pr} and B_{lim} when spawning biomass drops below specified reference levels. Lower: A further constraint is added to the upper type of rule, which may be based on biological or social constraints (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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References
Aubrey, D., S. Moncheva, E. Demirov, V. Diaconu and A. Dimitrov. (1996). Environmental changes in the western Black Sea related to anthropogenic and natural conditions. J. Marine systems, Vol 7, (2-4), p 411-425.

Berdnikov, S.V., V.V. Selyutin, V. Vasilchenko and J.F. Caddy (1999). Trophodynamic model of the Black and Azov Sea pelagic ecosystem: consequences of the comb jelly, *Mnemiopsis leydei* invasion. J. Fish. Res. 42, pp 261-289.

Caddy, J.F. (1993). Towards a comparative evaluation of human impacts on fishery ecosystems of enclosed and semi-enclosed seas. Reviews in Fisheries Science 1(1): p 57-95.

Caddy, J.F. (1999). Deciding on precautionary management measures for a stock based on a suite of limit reference points (LRPs) as a basis for a multi-LRP harvest law. NAFO Sci. Coun. Stud. 32, pp 55-68.

Caddy, J.F. (2000). Marine catchment basin effects versus impacts of fisheries on semi-enclosed seas. ICES J. Mar. Sci. 57: p 628-640.

Caddy, J.F. (2002). A general approach to monitoring changes in the Black Sea ecosystem, the status of fisheries resources, and socio-economic context, by establishing indicator time series in support of management decision-making. (Discussion Paper for the Workshop on Responsible Fisheries in the Black Sea and the Azov Sea). 35 p.

Caddy, J.F. (2004).Current usage of fisheries indicators and reference points, and their potential application to management of fisheries for marine invertebrates. Can. J. Fish. Aquat. Sci. (in press).

Caddy, J.F. and D. Agnew. (2003a). Recovery plans for depleted fish stocks: an overview of global experience. ICES Doc CM 2003/Invited lecture 2, 58p.

Caddy J.F. and D. Agnew (2003b).A summary of global stock recovery plans for marine organisms, including indicative information on the time to recovery, and associated regime changes that may affect recruitment and recovery success. ICES CM 2003/U:08 ; 42p.

Caddy, J.F., E. Duzgunes and K. Prodanov. (2004). Monitoring changes in the Black Sea ecosystem and fisheries using indicators in support of management decision-making. (Informal document of the Black Sea Commission, Istanbul).

Caddy, J.F. and L. Garibaldi (2001). Apparent changes in the trophic composition of world marine harvests: the perspective from the FAO capture database. Ocean and Coastal Management 43, p 611-655.

Caddy, J.F. and R. Mahon (1995). Reference points for fisheries management. *FAO Fish.Tech.Pap.*, 347:83 p.

Christensen V. and J. F. Caddy (1993). Reflections on the pelagic food web structure in the Black Sea. (FAO Fish. Rep. No. 495 Annex IV, p 60-77; ICLARM Contribution 881).

Daskalov, G.M. (1999). Relating fish recruitment to stock biomass and physical environment in the Black Sea using generalized additive models. Fish. Res. Vol 41, pp 1-23.

Daskalov, G.M. (2002). Overfishing drives a trophic cascade in the Black Sea. Marine Ecology Progress Series 225, p 53-63.

de Leiva Moreno, J.I., V.N. Agostini, J.F. Caddy and F. Carocci. (2000). Is the pelagic-demersal ratio from fisheries landings a useful proxy for nutrient availability? A preliminary data exploration for the semi-enclosed seas around Europe. ICES Journal Mar. Sci. 57: p 1091-1102.

FAO. (2001). Second technical consultation on the suitability of the CITES criteria for listing commercially-exploited aquatic species. FAO Background Document for the 2nd Technical Consultation on the suitability of CITES criteria for listing commercially-exploited aquatic species. FAO Doc. FI:SLC2/2001/2.,19p.

Fiorentini, L. and J.F. Caddy and J.I. de Leiva (1997). Long- and short-term trends of Mediterranean fishery resources. GFCM Stud.Rev., 69:72 p.

GESAMP (1995). Report of the twenty-fifth session of GESAMP, Rome, 24-28 April 1995. GESAMP Reports and Studies No 56, 54p.

Gilbert, D.J., J.H. Annala, and K. Johnston.(2000). Technical background to fish stock indicators for state-of-environment reporting in New Zealand. Mar. Freshwater Res. Vol 51, p 451-64.

Gucu, A.C. (2002). Can overfishing be responsible for the successful establishment of *Mnemiosis leidyi* in the Black Sea? Estuarine, Coastal and Shelf Science Vol 54 (3), pp 439-451.

Halliday, R.G., L.P. Fanning and R.K. Mohn. (2001). Use of the traffic light method in fishery management planning. Canadian Science Advisory Secretariat, Res. Doc. 2001/108, 41 p.

ICES (1997). Report of the comprehensive fishery evaluation working group. Doc CM 1997/Assess:15; 173p.

Jennings, S., S.P.R. Greenstreet, L. Hill, G.J. Piet, J.K. Pinnegar and K.J. Warr. (2002). Long term trends in the trophic structure of the North Sea fish community: evidence from stable-isotope analysis, size-spectra and community metrics. Mar. Biol. 141, p 1085-1097.

Kideys, A.E. (1994). Recent dramatic changes in the Black Sea ecosystem: the reason for the sharp decline in Turkish anchovy fisheries. J. Marine Systems, Vol 5(2), pp 171-181.

Koeller, P., L. Savard, D.G. Parsons and C. Fu. (2000). A precautionary approach to assessment and management of shrimp stocks in the Northwest Atlantic. J. Northw. Atl. Fish. Sci., Vol 27, p 235-246.

Mutlu, E., F. Bingel, A.C. Gucu, V.V. Melnikov, U. Niermann, N.A. Ostr, and V.E. Zaika. (1994). Distribution of the new invader *Mnemiopsis sp*. and the resident *Aurelia aurita* and *Pleurobrachia pileus* populations in the Black Sea in the years 1991-1993. ICES J. Mar. Sci. 51, p 407-421.

Patterson, K. (1992). Fisheries for small pelagic species: an empirical approach to management targets. Rev. Fish. Biol. Fisheries 2: p 321-338.

Pauly, D, V. Christensen, V. Dalsgaard, R. Froese, and F. Torres (1998). Fishing down marine food webs. Science 279, pp 860-863.

Prodanov, K., K. Mikhailov, C. Maxim, A. Chashchin, A. Arkhipov, V. Shlyakhov and E. Ozdamar. (1997). Environmental management of fish resources in the Black Sea and their rational exploitation. GFCM Stud. Revs. 68, 178p.

Prodanov, K. and K. Mikhailov. (2003). Possibilities for applying Jones' methods for turbot stock assessment and catch projection in the Black Sea. Workshop on demersal resources in the Black Sea and Azov Sea. 15-17 April 2003, Sile- Turkey.

Rass, T.S. (2001). The Black Sea region and its productivity. J. Ichthyology, Vol 41 (9).

Rochet, M.-J. and V.M. Trenkel. (2003). Which community indicators can measure the impact of fishing? A review and proposals. Can. J. Fish. Aquat. Sci. 60: p 86-99.

Seijo, J.C. and J.F. Caddy (2000). Uncertainty in bio-economic reference points and indicators of marine fisheries. Mar. Freshwater Res. 51, pp 477-483.

Sissenwine, M.P. and J.G. Shepherd (1987). An alternative perspective on recruitment overfishing and biological reference points. Can. J. Fish. Aquat. Sci. 44: p 913-918.

Trenkel, V.M. and M.-J. Rochet. (2003). Performance of indicators derived from abundance estimates for detecting the impact of fishing on a fish community. Can. J. Fish. Aquat. Sci. 60, p 67-85.

Zaitsev, Yu. P. (1993). Impacts of eutrophication on the Black Sea fauna. In: Fisheries and environmental studies in the Black Sea system, 63-85 pp. GFCM Stud. Rev. 64.

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. **Mussels (range, quality of meats)**	All **All(not Russia)**	Local resources. But suggest a cooperative focus on lagoon restoration, including aquaculture applications. (A range of environmental data collected, incl. bottom water oxygen, resource contaminants). Cooperative studies/programmes of contamination

	Venus clam (range)	All	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, <u>range</u>	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. - *Dolphins (bycatch, range, sightings)* - Rays (range) - *Phyllophora*	Danube countries, Russia, Georgia, Ukraine + Turkey (lead role Romania) *Salmon:Lead role Georgia, Turkey. Shads: Lead role Romania+ other Danube countries.* All All	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. ACABAS, Bonn Convention linkages. Compare current catch, size, distribution to historical data. Monitor area of seaweed beds.

		Ukraine	
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 web exploitation.	All	A general indicator of degree of exploitation of the ecosystem.
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.

RECRUITMENT TRENDS BASED ON TRAWL SURVEY DATA. ANALYSIS OF THEIR ROBUSTNESS

FERRANDIS E., LLORIS D., HERNÁNDEZ P., DE SOLA L.G.

D.to De Estadisatica – Universidad de Alicante

In the present work, recruitment trends based on survival analysis obtained from direct surveys data are considered. Recruitment is also analysed through commercial data.

Robustness of the trends and estimations is discussed using both: real data from direct surveys and simulated data.

SIMULATION OF DIFFERENT MANAGEMENT SCENARIOS BASED ON THE SPAWNING STOCK BIOMASS LEVEL. THE CASE OF RED MULLET (*MULLUS BARBATUS* L., 1758)

[1]SPEDICATO M.T., [1]CARBONARA P., [2]RINELLI P., [1]SILECCHIA T., [1]LEMBO G.

[1]Coispa Tecnologia & Ricerca, Stazione Sperimentale per lo Studio delle Risorse del Mare, Via dei Trulli 18-20; 70045 Bari (Torre a Mare), Italy, e-mail: spedicato@coispa.it
[2]IAMC-CNR Sezione di Messina, Messina, Italy

The biological reference points often reflect the combination of several components of stock dynamics (growth, recruitment and mortality) into a single index. Recently, also the evaluation of the operational interactions among different fish stocks and the environment represents a relevant challenge. 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 searching for new RPs more capable of accounting for the biological and technical specific characteristics of the area.
The objective of this paper is to test a BRP based on the spawning stock biomass (SSB), using as a 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 or vectors by size) were the input of a partially stochastic simulation model (biomass pool dynamic model) based on the Thompson & Bell approach.
The condition of *M. barbatus* stock was modelled accounting for fluctuations in the growth parameters, recruitment and maturity. In addition, different management scenarios (441 runs for each data set) were simulated changing total mortality Z and size at the first capture $L_{50\%}$ within a pre-defined range.
The results showed that variations of total mortality would be more effective then those of the size at first capture. Thus, a harvest strategy based on the total mortality decrease would produce more advantages then increasing the size at first capture. Suitable management options could thus be represented by the enforcement of the area and temporal closure.

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

[1]UNGARO N., [1]CERIOLA L., [1]MARANO C.A., [2]OSMANI K., [3]MANNINI P.

[1]Laboratorio Provinciale di Biologia Marina di Bari. Molo Pizzoli (Porto), 70123 Bari - Italy
E.mail: biologia.marina@teseo.it
[2]Fisheries Research Institute. Durres, Albania.
[3]FAO-Adriamed Project. Termoli, Italy.

The identification and use of suitable indicators and their reference points for fisheries management are 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 (GSA 18) from 1996 to 2003.

The aim was to identify a first set of indicators characterised by the following desirable features:

- easy compilation and processing procedures
- minimization of basic assumptions
- reliable performance with respect to interactions between fishery, environment and resources
- applicable to different scenarios
- comprehensibility for all stakeholders
- easy integration and comparison to eachother and with indicators from other sources (e.g. indirect methods, fishery-dependant information, economic and environmental indicators, etc.).

The trajectories of some population indicators such us arithmetic and geometric mean, median, and 75th percentile, were analysed for both biomass and abundance indices of two main "target" species for the south Adriatic demersal fishery: the European hake and the Deep-water rose shrimp. 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 multispecies 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.

The proposed indicators from direct methods could be useful to establish a wider multidisciplinary poly-indicator score panel for the Adriatic Sea fisheries, taking advantage of the FAO-AdriaMed regional cooperation framework.

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

SABATINI A., CUCCU D., MURENU M., FOLLESA M.C., CAU A.

DBAE – Università di Cagliari - Viale Poetto 1, 09126 Cagliari, Italy

The identification of correct Biological Reference Points (BRP) regarding the Mediterranean stock has been a theme of recent close study. To deepen knowledge of this topic the temporal evolution of *Aristaeomorpha foliacea* has been analyzed in three geographical areas of distinct exploitation: Southern, South-Eastern and South-Western Sardinia. To advance this undertaking specific analysis was given to the processed data from the MEDITS trawl surveys between 1994 and 2003.
The aim of this study is to identify which BRPs are realistically applicable and compatible with the objectives of precautionary resource management, through the application of diverse models of assessment for the afore mentioned geographical areas.
Particular attention was given to the analysis of biomass index trends and the demographic evolution in each of the three geographic zones. The length frequency distributions of each year were divided into age groups. The estimates of mortality have been valued by means of comparative analysis of biomass decrease of each age cohort over several years. Furthermore, application of the Beverton and Holt *Yield per Recruit* model to fishing mortality rates over several years was compared to valued reference points ($F_{0,1}$, $F_{0,5}$, F_{max}).
These results have been compared in relation to the temporal evolution of trawler fishing fleets so to determine which BRPs are realistically achievable and sustainable.

TWIN TOOLS TO GET BACK TO SUSTAINABLE FISHING:
SHIFTING + PRIZE AWARDING:

LEVI D.

Dino.Levi@irma.pa.cnr.it

Whichever Ref. Point is chosen, implementing controls in fisheries is generally a loosing bet.

Two new tools, if applied jointly, could result effective: I) shifting in time a compulsory fishing ban to affect the excess effort exerted by a fleet, stopping time being equal to excess effort; II) awarding monetary prize for quality (i.e. $\simeq$ size) of landed fish.

Discussion on the above is highly sought.

LOOKING FOR REFERENCE POINTS FOR THE MEDITERRANEAN SWORDFISH FISHERY

PALANDRI G., GARIBALDI F., CIMA C., LANTERI L., ORSI RELINI L.

Dip.Te.Ris., Laboratorio di Biologia Marina ed Ecologia Animale,
Università di Genova, Corso Europa, 26 – 16132 Genova, Italy
E-mail: largepel@unige.it

Several teams studying the biology and fishery of swordfish in the Italian Seas, have been recently involved in the first Mediterranean attempts of measuring recruitment processes in this species.
The interest of this kind of research was suggested by ICCAT to the Italian MiPAF; in ICCAT studies, recruitment indexes of large pelagic fish, such as swordfish or bluefin tuna, are presented in the framework of VPA assessment, when the structure of the fished stock is studied in details in temporal series (Miyake and Rey, 1989); they are also related to large scale climatic or oceanographic factors (Mejuto 1999, 2000, 2001, 2003; Santiago 1998; Borja and Santiago 2002).
In the present note we recall the main biological parameters of the swordfish in our study area, the Ligurian Sea; we present temporal series of both longline CPUE (kg per 1000 hooks) and recruitment indexes and discuss possible relationships between recruitment levels and abundance of spawners.
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) are now included in a “Cetacean Sanctuary” recently established on the basis of international agreements (2001); however since 1990, the Italian governement introduced a ban of driftnets 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.
The CPUE of swordfish longlines (kg / 1000 hooks) since 1992 are growing. The recruitment index, in terms of N of fish aged 1 per 1000 hooks, doesn’t show a positive trend but is oscillating around an average of 1.6, a figure which appears higher than in oceanic longline fisheries; on the contrary the adult fish abundance is growing.
We try to discuss the significance of this data.

SELECTION OF POSSIBLE INDICATORS OF SUSTAINABLE YIELD FROM TOTAL MORTALITY RATES FOR *MULLUS BARBATUS* IN THE GFCM GEOGRAPHIC SUB-AREA 9.

[1]ABELLA A., [2]CARPENTIERI P., [3]MANNINI A., [4]SARTOR P., [4]VIVA C., [1]VOLIANI A.

[1]Agenzia Regionale Protezione Ambiente Toscana, Sez. GEA Via Marradi 114, 57127 Livorno, Italy
[2]Dipartimento Biologia Animale e dell'Uomo, Università di Roma, Via dell'Università 32, 00184 Roma, Italy
[3]Istituto di Zoologia, Università di Genova, Via Balbi 5, 16126 Genova, Italy
[4]Centro Interuniversitario di Biologia Marina (CIBM), 57127 Livorno, Italy

The precautionary approach for fisheries, as specified in the FAO Code of Conduct, is related to conservation, management and exploitation of the living resources and the aquatic environment. In order to improve decision-making for resources conservation and fishery sustainability, management tools should be based on scientific evidence allowing the definition of stock specific target and limit reference points.

In this paper, reference points derived from 3 different population dynamics approaches have been tested for the red mullet *Mullus barbatus,* one of the most important l species exploited by the bottom trawlers of the studied area, comprising the continental shelf bottoms of Ligurian, Northern and Central Tyrrhenian Seas (Western Mediterranean).

The choice of these biological reference points was based on their potential feasibility, taking into consideration the current knowledge of the fisheries that exploit the mentioned resource, as well as the life-cycle and reproductive aspects of this species. Data proceed from national and international trawl surveys performed in the investigated area between 1994 and 2003, in spring and autumn of each year. For each survey, the size structure of the stock as well the abundance and density indices were obtained for the whole area. Subsequently, the size-frequency distribution of each sex have been investigated, by modal progression analysis, in order to select different demographic components and to estimate their abundance.

Spawning Stock/Recruitment models describe the likely relationship between adult population (Spawners) and the new generation (Recruits). The approach utilised in the present work is based on the concept of Fmed (and the related Flow and Fhigh) (ICES, 1984, 1985) and successively developed by Sissenwine and Shepherd (1987). It allows the identification of the level of fishing mortality linked to the replacement of the spawning biomass that should guaranty adequate and sustainable yields. In practice, Fmed corresponds to the level of Fishing mortality where the accessions to the stock by recruitment have been in about half of the observed years and they are enough to balance the losses due to mortality. In consequence, if fishing is maintained at this rate, the stock will be sustained. Fmed is considered a limit reference point.

In this work, the estimates of the parental stock (in numbers of individuals per km^2) and the respective number of recruits 6 months after were coupled and displayed in a scatter diagram. The reference points Zcrash and Zmed, linked to the replacement of the spawning biomass, were estimated

Dynamic pool models describe the changes in biomass of a cohort after recruitment and allow the estimation of the yields, yields per recruit, spawners per recruit that is likely to be determined by any combination of age or size of recruitment to the fishery and level of fishing pressure.

Spawning per recruit (SPR) analysis is an extension of the dynamic pool model used for the computations of yield per recruit (Y/R) at different levels of fishing mortality. While the maximum values for the Y/R are generally obtained at intermediate levels of fishing pressure, SPR follows a monotonous decline as F increases. In this study, simulations based on the Thompson & Bell (1934) yield forecast approach were made allowing to assess the consequences in yields and biomass per recruit produced with alternative combinations of size of first capture and exploitation rates. They allow the definition of the level of F that reduces the ratio SSB to a certain percentage of the pristine level SSB_0.

Biomass dynamic models describe production as a function of biomass and some times production as a function of fishing pressure. In general, they work as a "black box" and do not need of explicit modelisation of recruitment, growth or natural mortality processes. However, they need not to be heuristic and some times they can be derived through combinations of S/R and dynamic pool models.

Results presented in a published paper (Abella et alii. 1997) utilising the Caddy and Csirke (1983) variant of surplus production modelling with the annual total mortality rate (as a direct index of fishing effort) and the mean catch per hour fishing (as index of abundance) were compared with those proceeding from the other approaches. Due to the lacking of long data series, the need of an equilibrium assumption and contrasting enough data on catch and effort, in the mentioned paper the Caddy and Csirke model was combined with a composite model (Munro, 1980), that use spatial information proceeding from ecologically similar sub-areas exploited at different rates.

The third approach tested in this work was that proposed by Die and Caddy (1997) which defined the reference point $Z*$, aimed at a roughly 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 of first maturity, *Lm*, and the size of first capture *Lc* 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. It is likely that in these circumstances the sustainability of the population biomass is guaranteed. All the above mentioned analyses have been performed at wide geographical level (GFCM Sub-Area 9), after having tested them at reduced scale, taking into account different geographical sectors of the studied area, more homogeneous as regards to resource availability, fishing pressure and fishing pattern.

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.

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

GRAMOLINI R., MANFREDI C., PICCINETTI C.

Laboratorio di Biologia Marina e Pesca dell'Università di Bologna,
V.le Adriatico 1/n, 61032 Fano (PS), Italy

The possible use of simple indicators of state of demersal stock in the Adriatic SGA 17 is verified by use of Medits data.
For *Merluccius merluccius*, *Mullus barbatus*, *Nephrops norvegicus* and *Loligo vulgaris* those indicators are calculated:

- Abundance index (total number of individuals for km²)
- Biomass index (total weight for km²)
- number of recruits for km²
- number of spawners for km²
- ratio between recruitment and spawners of the previous year
- calculation of Mean, Median and Mode values for all individuals
- calculation of Mean, Median and Mode values for adults.

The results show:

- the influence of recruitment on density and biomass indices of entire population
- the high variability of recruitment during the years
- the utility in few case, to use density index or at a fixed lengths or at a fixed age for a best evaluation of the recruitment
- the interest in the use of number of spawners for km² as reference points
- existence of many problems in the use of the ratio between number of recruits and number of spawners of the previous year cause the recruitment variability
- no clear relation between values of Mean, Median and Mode values: in few situation when density decrease, the values of size increase.

Further elaboration of many indicators are necessary to fix other values for limit reference points.

TOWARD THE ESTABLISHMENT OF REFERENCE POINTS TO MANAGE THE FISHERIES IN THE STRAIT OF SICILY

[1]RAGONESE S., [1]BIANCHINI M.L., [2]CAMILLERI M., [1]DE SANTI A., [1]FIORENTINO F., [1]GRISTINA M., [1]GAROFALO G., [1]MORIZZO G.

[1]MaLiRA-Group, Ist. Risorse Marine e Ambiente (IRMA), sez. IAMC/CNR, Via Vaccara 61, 91026 Mazara (TP), Italy
[2]Malta Centre for Fisheries Sciences (MCFS), DFA-MAF, Malta.

In the peculiar situation of the Strait of Sicily, one of the most important fishing area of the Mediterranean, the Marine Living Resources Assessment Group (MaLiRA-Group), of the Institute of Marine Resources and Environment (IRMA) of the Italian National Research Council (CNR) is trying to establish, using data gathered with trawl surveys campaigns (programs GRUND and MEDITS), reference points for managing the fisheries, based on reliable and in the same time easy indicators of the status of the resources; at present, three different approaches are under conceptual and methodological development and verification.

Assuming there are consistent time series, robust reference points are obtained with trawl surveys data only, employing some critical values of the total mortality Z, i.e. Z_{low}, Z_{med}, Z_{high} and Z_{loss}, which are linked to the resilience of the resources; in fact, only abundances of recruits and spawning stock, length(age) frequency distributions and estimates of Z are required.

Since a large amount of estimates by species is regularly presented in trawl surveys reports and given that any in-depth analysis requires considerable effort and time, it seems interesting to use the already available estimates as rough indicators of the consistency in time of the trawl series. With this in mind, a set of variables (specifically, mean abundance indexes in weight, mean body weight, overall median length, overall sex-ratio, sex-ratio by selected length-class, mean and median female length at different maturity stages, percentage of females in the different maturity stages) by each survey are considered together on some target species, providing a displacement measure of the overall "center of gravity". Univariate and multivariate techniques (among years, differences are tested by each species with 8-side kite diagrams and for all species combined using a MDS approach) are applied to produce indicators reflecting any overall change in the exploitation and status of the target species.

A multi-species index (BOI), defined as the ratio between "bottom-dwelling fish" and "overall fish" biomasses, is proposed as bio-indicator of the status of the demersal fish assemblages. This simple tool is based on the empirical consideration that trawling removes from a fish assemblage the bottom-dwelling and less mobile animals first. Comparisons of heavily trawled *vs*. almost pristine areas, and analysis of time series of catch rates in areas showing a decrease of trawling effort, suggest that the BOI could be broadly used as quantitative proxy of the trawling impact on the various demersal assemblages, being able to discriminate, especially when used in association with standing biomass representations, to discriminate areas exploited with different trawling pressure.

None of the above indicators is completely self-sufficient but, used together, they offer the possibility of a link between the scientific results regularly provided by trawl surveys and the ecosystem approach to fisheries (EAF).

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

SANTOJANNI A., CINGOLANI N., ARNERI E., BELARDINELLI A.,
GIANNETTI G., COLELLA S., DONATO F.

CNR-ISMAR, Sezione Pesca Marittima, Largo Fiera della Pesca 1, 60125 Ancona, Italy
e-mail: n.cingolani@ismar.cnr.it

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 Patterson (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 based on spawning stock biomass, actually 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.

REFERENCE POINTS BASED ON SURVIVAL ANALYSIS: MORTALITY RATES (NATURAL, TOTAL, FISHING), EXPLOITATION RATE, LIFE EXPECTANCY AND MEDIAN SURVIVAL TIME. COMPARISON OF THEIR ROBUSTNESS USING REAL AND SIMULATED DATA.

FERRANDIS F., LLORIS D., HERNÁNDEZ P., CAMPO M., DE SOLA L.G.

D.to De Estadisatica – Universidad de Alicante

In the present work, different reference points commonly used on demersal fishery management, are considered. Their estimation is based on conditional survival obtained from direct surveys data.

Robustness of those parameters is discussed by using three different types of data: direct surveys data, commercial published data and simulated catches data.

A general methodology for the simulations and for the robustness analysis in different scenarios is proposed.

Paper presented at the International Symposium “Quantitative Ecosystem Indicators for Fisheries Management”. IOC-SCOR WG 119. Paris, 31 March-3 April 2004.

DEVELOPING AN OPERATIONAL REFERENCE FRAMEWORK FOR FISHERIES MANAGEMENT BASED ON THE COMPOSITE INDICATOR PPR-TL_{CATCH}

[1]TUDELA S., [2]COLL M., [2]PALOMERA I.

[1] WWF Mediterranean Programme. Canuda, 37. 08002 Barcelona. Spain. studela@atw-wwf.org
[2] Institut de Ciències del Mar (CSIC). Passeig Marítim de la Barceloneta, 37-49. 08003 Barcelona. Spain.

1. Introduction and objectives

The development of quantitative ecosystem-based indicators is key to deliver a fully operational Ecosystem Approach to Fisheries (EAF). Overfishing has been identified as the main destabilising factor and the main component of major structural and functional changes on marine ecosystems(31,46). It drives marine species to ecological extinction, making ecosystems more vulnerable to collapse, and it has been a precondition of collapse of coastal ecosystems in recent times due to human disturbances(31). In this context, the composite indicator PPR-TL_{catch}, the percentage of the primary production required to sustain fisheries (PPR)(45, 21) and the average trophic level of the catch (TL_{catch})(21,33,46), was proposed as a quantitative ecosystem indicator suitable for fisheries management (Figure 1)(57,58). The informative value of the composite indicator with respect to Ecosystem Overfishing (EO) relies on supplementary ecological information, such as occurrence of massive resource collapses and indicators on development, structure and functioning of ecosystems(17, 42).

This work presents the development of this composite indicator and the definition of a quantitative boundary for EO susceptible to support an Ecosystem-Based Operational Reference Framework (EBORF) for fisheries management. The intrinsic nature of EAF as a precautionary approach leads to the establishment of limit reference functions, related to precautionary buffer areas instead of the usual target references envisaged in conventional target resources oriented management(26).

Theoretical Framework (Fig. 1). Excluding potential effects on trophic webs of the removal of keystone species or unexpected trophic cascades, scenario *b* is intrinsically less disrupting as regards to the ecosystem functioning than scenario *a*, as it keeps an important flow of energy towards upper TLs, thus allowing for the maintenance of ecologically functional ecosystem components in the lower and middle position of food web. If the intensity of harvesting is very much increased at the same TL, there would exist a likely threshold in between scenario *a* and *c* beyond which the functional and structural properties of the ecosystem become undermined.

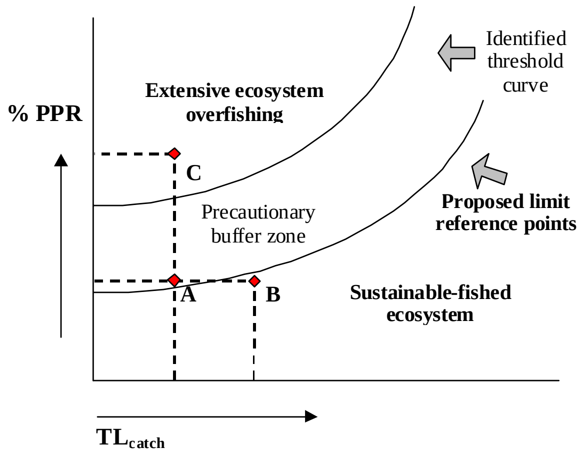

Figure 1. General theoretical framework based on the composite indicator PPR-TL_{catch} and ecosystem overfishing(57,58).

2. Methodology

1. Pairs of PPR-TL_{catch} were compiled from ecological models[21] from different areas and periods of time. PPR was compiled as primary production required to sustain fisheries from a) primary producers and b) primary producers plus detritus. For each case, it was analysed whether it qualified for 1) sustainable-fished, non-disrupted ecosystem, with main ecosystem functioning and structure preserved, or 2) overfished ecosystem, involving structural and functional degradation, usually associated to stock collapses and overall overexploitation of marine resources. Cases were classified considering to fit in the ecosystem overfishing (EO) status when cumulative impacts of fishing were reported to have resulted in one or more of the symptoms of EO definition[32,38]. The categorisation entailed the analysis of 1) various Ecopath-derived ecological indices related to ecosystem development, chosen among those described to better assess changes on ecosystem structure and functioning with fishing [17,20,29,30,42,60] and 2) supplementary ecological information from scientific literature and non-published sources. Classified cases are listed in Table 1, while cases without enough information available to allow a proper classification are listed in Table2.

2. Canonical Discriminant Analysis (CDA) was performed on the data set defined by classified pairs of PPR-TL_{catch} and the associated discriminant function was obtained. Discriminant function was used to check the data set classification efficiency and results were then applied to define the ecosystem-based operational reference framework (EBORF) for fisheries management. Limit reference functions were established by assessing changes in probabilities associated to pairs of PPR-TL_{catch} and were defined as threshold functions containing cases with 50%, 70%, 90% and 95% of probabilities of belonging to a sustainable-fished ecosystem situation.

3. CDA were then applied to unclassified cases in Table 2 and results were analysed based on partial information available. Finally, the EBORF proposed was applied to estimate Ecosystem-Based Maximum Sustainable Catches (EBMSC) for different ecosystem types associated to probabilities of 50% and 70% of belonging to sustainable-fished ecosystems ($EBMSC_{50}$ and

$EBMSC_{70}$). This approach was specifically applied to the Mediterranean Sea. The assessment was done by modifying the equation used to calculate PPR[45] and using the limit reference functions.

Table 1. Ecosystem models included in the analysis that could be classified according to the ecosystem overfishing criteria[32,38]. Models are listed by main ecosystem types.

	Ecosystem models [Ref.]	C [1]
A.	**Temperate shelves and seas**	
1	Faroe Islands (1961) [62]	2
2	Icelandic fisheries (1950) [7]	2
3	North Sea (1880) [34]	2
4	North Sea (1963) [FC]	1
5	North Sea (1974) [FC]	1
6	North Sea (1981) [16]	1
7	Newfoundland (1900) [29, 52]	2
8	Newfoundland (1985-1987) [10, 29, 52]	1
9	Newfoundland (1995-2000) [10, 29, 52]	1
10	Norwegian and Barents Sea (1950) [25]	2
11	Eastern Bering Sea (1950s) [56]	2
12	Eastern Bering Sea (1980s) [56]	1
13	N. Brithish Columbia (1750) [1]	2
14	N. Brithish Columbia (1900) [1]	2
15	N. Brithish Columbia (1950) [1]	1
16	N. Brithish Columbia (2000) [1]	1
17	N. Gulf of Sant Lawrence (1985-87) [FC]	2
18	Lancaster Sound Region (1980s) [37]	2
19	Georgia Strait (1950) [47]	2
20	West Greenland shelf (1997) [48]	1
21	Scotian shelf (1980-1985) [12]	2
22	NW Mediterranean (1994-2000) [23]	1
23	Azores archipelago (1997) [27]	2
24	Cantabrian Sea (1994) [53]	1
B.	**Tropical shelves and seas**	
25	Gulf of Thailand (1963) [18]	2
26	Gulf of Thailand (1980s) [18, 44]	1
27	Gulf of Thailand (1993) [FC]	1
28	SW coast of India (1994) [49]	1
29	SW coast of India (1995) [49]	1
30	SW coast of India (1996) [49]	1
31	S. shelf of Brasil (1975-79) [59]	1
32	S. shelf of Brasil (1990-94) [59]	1
33	SE shelf of Brasil (1977-80) [59]	1
34	SE shelf of Brasil (1990-95) [59]	1
35	Venezuela NE shelf (1980s) [35]	1
36	Gulf of Mexico cont. shelf (1990s) [6]	1
37	Brunei Darussalam (1980) [54]	2
38	Vietnam-China shelf (1980) [44]	2
39	S. China Deep Sea (1980s) [44]	2
40	Hong Kong (1990s) [8, 14]	1
41	Bay of Bengal (1984-86) [39]	1
42	San Pedro Bay (1994-95) [13]	2
C.	**Coastal areas and coral reefs**	
43	Bay of Revellata, Corsica (1998) [50]	2
44	Prince William Sound (1994-96) [43]	2
45	W coast Gulf of Mexico (1990s) [3]	1
46	Gulf of Lingayen (1990s) [44]	1
47	Maputo Bay (1980s) [24]	1
48	San Miguel Bay (1992-94) [11]	1
49	Boliano reef flat (1991) [2]	1

(1): Classification, 1.Overfished-ecosystem; 2.Sustainable-fished ecosystem; (Ref.): Reference number (see below).

Table 2. Ecological models classified within the ecosystem-based operational reference framework (Figure 2). Models are listed by main ecosystem types.

	Ecosystem models (Ref.)	C (1)
A.	**Temperate shelves and seas**	
1	Faroe Islands (1997) (62)	Recovering from highly exploitation.
2	Icelandic fisheries (1997) (36)	Fished biomass decrease and cod heavily fished.
3	Norwegian and Barents Sea (1997) (25)	Mediu-high exploitation regime.
4	Central N. Pacific (1998) (FC)	Top predators fishery.
5	W. Greenland shrimp trawling area (1994) (48)	Shift regime from cod to shrimp. Important cod bycatch.
6	Gulf of Maine - Georges Bank (1982) (28)	Highly exploited.
7	Atlantic coast of Morocco (1980s) (55)	Highly fished.
B.	**Tropical shelves and seas**	
8	Campeche Bank of Yucatan shelf (1990s) (4)	Highly exploited with some overexploited resources.
9	Gulf of Thailand (1973) (FC)	Moderate fishing.
10	Kuala Trengganu (1980s) (15, 44)	Moderate fishing.
11	Bali Strait (1990s) (9)	Heavilly exploited, sardin maybe overexpl.
C.	**Coastal areas and coral reefs**	
12	Schlei Fjord (1984) (19)	Moderate fishing.
13	Beach seine of G. of Mexico (1990s) (61)	Fishing preasure has declined.
14	Shallow areas of Gulf of Thailand (1979) (44)	Small scale fisheries.
15	N. coast of central Java (1979-80) (41)	Highly fished.
16	N. Great Barrier Reef (1994-96) (FC)	Trawl resources fully-exploited.

(1): Information available, (Ref.): Reference number (see below).

3. Main results

The initial hypothesis on the behaviour of PPR and TL_{catch} with respect to ecosystem overfishing (EO) was confirmed and described with a power relationship (Figure 2).

Discriminant analysis showed high percentage of models correctly classified (87.8% when using PPR from primary producers). Exceptions were models corresponding to reconstructed situations from the past[51] with an important fishing pressure on marine mammals and high PPR. Newfoundland model (1985-87) was also reclassified by the discriminant function due to the special situation of the ecosystem right after the collapse of the cod fishery[29].

Figure 2 defines the Ecosystem-based operational reference framework (EBORF) for fisheries management and establishes different functions as threshold curves associated with different probabilities of belonging to sustainable-fished ecosystem situations. The sustainable-fished ecosystem area implies a fishing strategy based on TL_{catch} higher than 3.0 and low to moderate PPR.

Models compiled in the EO area are mainly characterised by fishing strategies based on small pelagic, small demersal fishes and invertebrates.

Results from the representation of ecological models from Table 2 within the EBORF are generally aligned with available partial information from these ecosystems (Figure 3).

Ecosystem-based maximum sustainable catches (EBMSCs) are lower than the reported catches for all ecosystem types analysed and for the Mediterranean sea (Table 3). This discrepancy is higher when accurately assessing a fishing system at a smaller scale, as is the case of the Catalan Sea, with $EBMSC_{50}$ being 4 times higher than the current harvest.

The above results were similar when considering PPR from primary producers plus detritus. However, on 63.33% of the cases PPR from primary producers was lower than when also considering detritus. This highlights the importance of detritus to sustain fisheries.

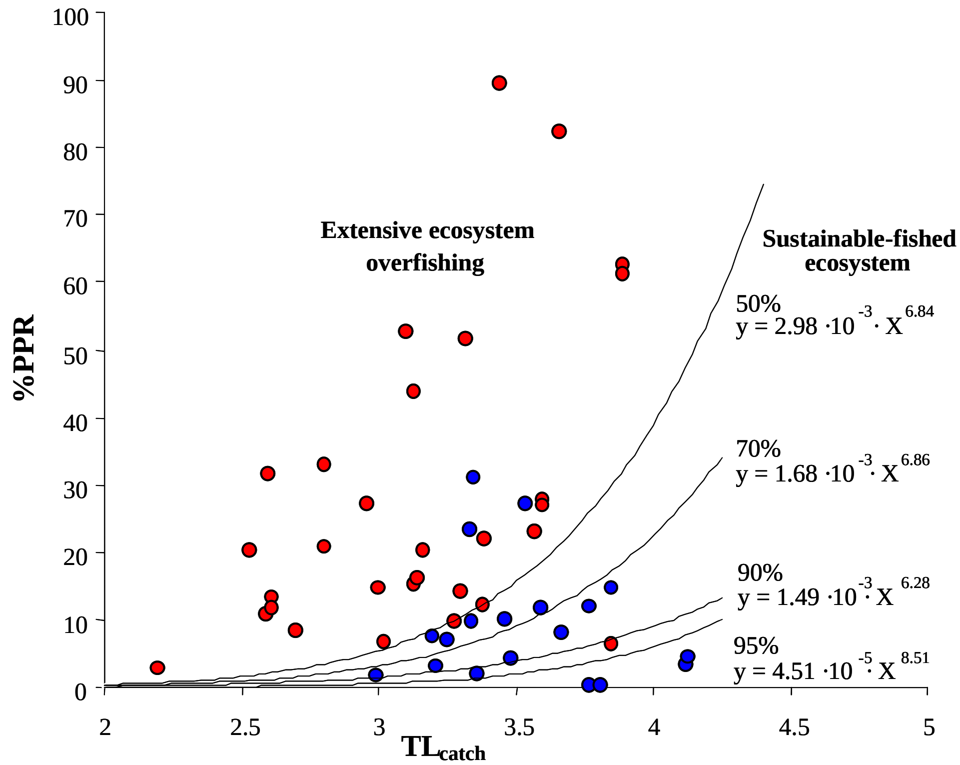

Figure 2. Ecosystem-based operational reference framework for fisheries management based on PPR-TL_{catch} from ecosystem models in Table 1. PPR from primary producers has been used.

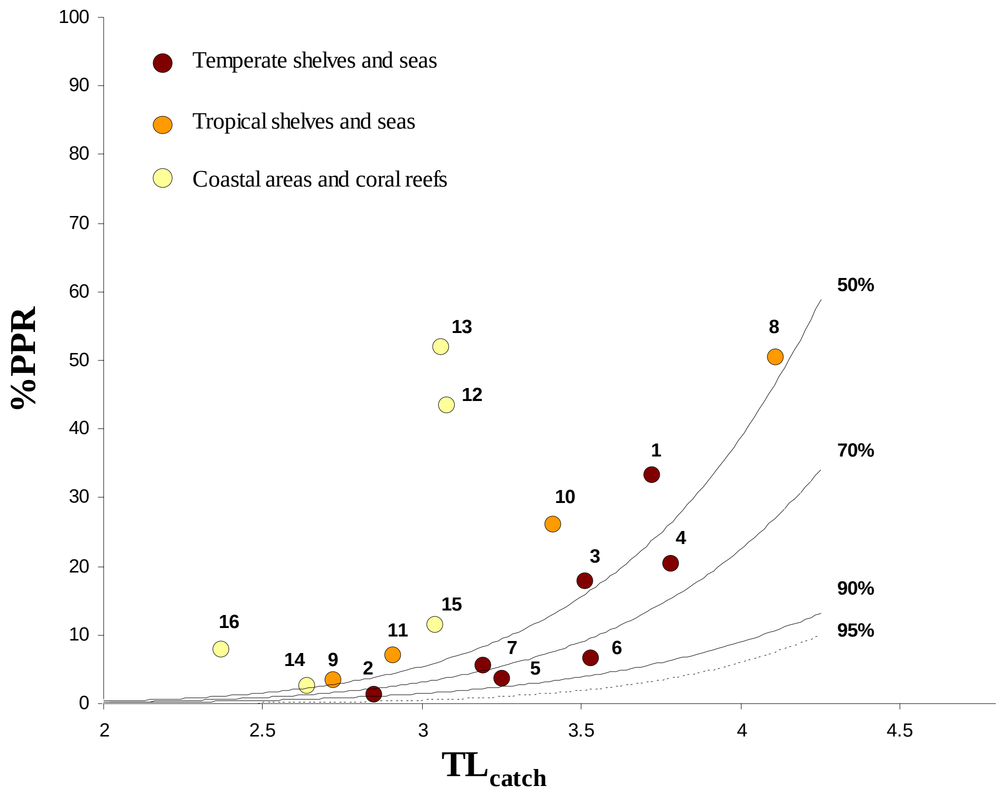

Figure 3. Pairs of PPR-TL_{catch} from ecosystem models in Table 2 represented within the ecosystem-based operational reference framework (Figure 2).

Table 3. Ecosystem-based maximum sustainable catches at the 50% and 70% of probability of being in a sustainable-fished situation for different ecosystem types and for the Mediterranean Sea.

Ecosystem type	PP [45] ($gC \cdot m^{-2} \cdot yr^{-1}$)	TL_{catch} [45]	Catch and discards ($t \cdot km^{-2} \cdot yr^{-1}$) [45]	$EBMSC_{50}$ ($t \cdot km^{-2} \cdot yr^{-1}$)	$EBMSC_{70}$ ($t \cdot km^{-2} \cdot yr^{-1}$)
Tropical shelves	310	3.3	2.87	1.46	0.84
Temperate shelves	310	3.5	2.31	1.38	0.80
Coastal areas and reefs	890	2.5	10.51	3.96	2.28

Region/area	PP ($gC \cdot m^{-2} \cdot yr^{-1}$)	TL_{catch}	Catch and discards ($t \cdot km^{-2} \cdot yr^{-1}$)	$EBMSC_{50}$ ($t \cdot km^{-2} \cdot yr^{-1}$)	$EBMSC_{70}$ ($t \cdot km^{-2} \cdot yr^{-1}$)
Mediterranean Sea	142 [5]	3.0 [46]	0.73 [*]	0.69	0.40
South Catalan Sea	232 [57]	3.13 [23]	5.10 [23]	1.13	0.65

[*] Fao statistics modified to consider discards and IUU (unpublished data), not considering Black Sea.

4. Discussion

The ecosystem-based operational reference framework (EBORF) for fisheries management is an important step towards the translation of concepts as "ecosystem overfishing", "ecosystem health" and "ecosystem integrity" into operational definitions(32).

Even if higher resolution can be achieved by incorporating new data, the current framework provides a general ecosystem-based evaluation of specific fishing strategy considering structure and functionality of marine ecosystems. New pairs of PPR-TL_{catch} above the limit reference functions informs on deviation from desirable situations in order to avoid ecosystem overfishing (EO).

Overfishing is met sooner following an increase in fishing exploitation intensity (PPR) operating at low TLs. Sustainable ranges for TL_{catch} and PPR values identified here highly contrast with current estimates available for the same ecosystem types[45]. This could have important consequences in the context of current trends on worldwide depletion of predator fishes and consequent descent of TL_{catch}[22,40].

Ecosystem-based maximum sustainable catches (EBMSCs) are related to maximum fishing intensity operating at a mean TL if wishing to keep a fishing strategy compatible with well-structured and functionally undisrupted marine ecosystem, with main ecological and evolutionary processes maintained. Higher catches would imply higher risk of EO, entailing an increase of vulnerability in the face of environmental variability and other anthropogenic activities.

Under the hypothesis of the reversibility of the effects of EO, the rational approach would require a substantial reduction of current catches towards EBMSC. Higher catches might be kept with chronically degraded ecosystems, though the long term viability of the situation is doubtful and large scale resource collapses can occur[31].

Results point to current fishing strategies being far beyond sustainable situations from the perspective of EO. This reinforces the need to apply a generous precautionary approach to fisheries management to include maintenance and recovery of biodiversity and functional redundancy within marine ecosystems, main factors preventing the functional collapse of ecosystems following major fishing impacts[31].

In the Mediterranean Sea new pairs of PPR-TLcatch from different Mediterranean fisheries could be also calculated and set within the presented ecosystem-based operational reference framework.
New pairs of PPR-TL_{catch} above the limit reference functions would inform on deviation from desirable situations in order to avoid EO. Ecosystem-based maximum sustainable catches would give us an idea of the current exploitation patterns in terms of sustainable-fished ecosystem context and set overall catch limits.

References

(1) Ainsworth, C. et al., 2002. *FCRR*, 10(4). 41 p.
(2) Aliñó, P.M. et al.,1993. *ICLARM Conf. Proc*., 26: 252-267.
(3) Arreguín-Sánchez, F. et al., 1993a. *ICLARM Conf. Proc.*, 26: 197-205.
(4) Arreguín-Sánchez, F. et al., 1993b. *ICLARM Conf. Proc*., 26: 269-278.
(5) Bosc, E. et al., 2004. *Global Biogeochem. Cycles*, 18.
(6) Browder, J.A.,1993. *ICLARM Conf. Proc*., 26: 279-284.
(7) Buchary, E., 2001. *FCRR*, 9(4): 198-206.
(8) Buchary, E. et al. 2002a. *FCRR*, 10(3): 6-16.
(9) Buchary, E. et al. 2002b. *FCRR*, 10(2): 24-32.
(10) Bundy, A., 2001. *Can. J. Fish. Aquat. Sci*., 58: 1153-1167.
(11) Bundy, A. and Pauly, D., 2001. *Fish. Res.*, 53: 263-281.
(12) Bundy, A. and Guénette, S., 2002. *FCRR*, 10(2): 112-117.
(13) Campos, L. W., 2003. *WorldFish Center Conf. Proc.*, 67 (in press).
(14) Cheung, W.-L., et al., 2002. *FCRR*, 10(2): 46-54.
(15) Christensen, V., 1991. *Fishbyte*, 9(2): 62-66.
(16) Christensen, V., 1995a. *Dana*, 11(1): 1-28.
(17) Christensen, V., 1995b. *Ecol. Model.*,, 77: 3-32.
(18) Christensen, V., 1998. *J. Fish Biol.*, 53(Suppl.A): 128-142.
(19) Christensen, V. and Pauly, D., 1992. *Ecol. Model.*, 61: 169-185.
(20) Christensen, V. and Pauly, D., 1998. *Ecol. Appl*., 8(Suppl.1): 104-109.
(21) Christensen, V. and Walters, C., 2004. *Ecol. Model.*, 172 (2-4): 109-139.
(22) Christensen, V. et al., 2003. *Fish and Fisheries*, 4: 1-24.
(23) Coll, M. et al., 2004. *4rt W. Fish. Congress, poster session*.
(24) De Paula e Silva., 1993. *ICLARM Conf. Proc*., 26: 214-223.

(25) Dommasnes, A. et al., 2001. *FCRR*, 9(4): 213-239.
(26) FAO, 2003. *Fao Fish. Tech. Paper*, 443. 71 pp.
(27) Guénette, S. and Morato, T., 2001. *FCRR*, 9(4): 271-313.
(28) Heymans, J. J., 2001. *FCRR*, 9(4): 129-149.
(29) Heymans, J. J., 2003. *FCRR*, 11(5). 81 p.
(30) Heymans, J. J. and Baird, D., 2000. *Ecol. Model*., 131: 97-119.
(31) Jackson, J. B. C. et al., 2001. *Science*, 293: 629-638.
(32) Larkin, P. A., 1996. *Rev. Fish. Biol. and Fish*., 6: 139-164.
33) Lindeman, R. L., 1942. *Ecology*, 23: 399-418.
(34) Mackinson, S., 2001. *FCRR*, 9(4): 35-98.
(35) Mendoza, J.J., 1993. *ICLARM Conf. Proc*., 26: 285-297.
(36) Mendy, A. N. and Buchary, E., 2001. *FCRR*, 9(4): 182-197.
(37) Mohammed, E., 2001. *FCRR*, 9(4): 99-110.
(38) Murawski, S. A., 2000. *ICES J. Mar. Sci*., 57: 649-658.
(39) Mustafa, M. G., 2003. *WorldFish Center Conf. Proc*., 67 (in press).
(40) Myers, R. A. and Worm, B., 2003. *Nature*, 423: 280-283.
(41) Nurhakim, S., 2003. *WorldFish Center Conf. Proc*., 67 (in press).
(42) Odum, E. P., 1969. *Science*, 104: 262-270.
(43) Okey, T. and Pauly, D., 1998. *FCRR*, 7(4). 146 p.
(44) Pauly, D. and Christensen, V., 1993. *Stress, mitigation and sustainability of Large Marine Ecosystems*. AAAS Press: 148-174.
(45) Pauly, D. and Christensen, V., 1995. *Nature*, 374: 255-257.
(46) Pauly, D. et al., 1998a. *Science,* 279 (5352): 860-863.
(47) Pauly, D. et al., 1998b. *FCRR*, 6(5). 99p.
(48) Pedersen, S. A. and Zeller, D., 2001. *FCRR*, 9(4): 111-127.
(49) Pillai, V. N. et al., 2003. *WorldFish Center Conf. Proc*., 67 (in press).
(50) Pinnegar, J.K., 2000. PhD Thesis, University of Newcastle, UK. 213pp.
(51) Pitcher, T.J., 2001. *Ecol. Appl*., 11: 601-617.
(52) Pitcher, T. et al., 2002. *FCRR*, 10(5). 76 p.
(53) Sánchez, F. and Olaso, I., 2004. *Ecol. Model*., 172(2-4): 151-174.
(54) Silvestre, G. et al., 1993. *ICLARM Conf. Proc*., 26: 300-306.
(55) Stanford, R. et al., 2001. *FCRR*, 9(4): 314-344.
(56) Trites, A. W. et al., 1999. *FCRR*, 7(1). 106 p.
(57) Tudela, S., 2000. *Ciesm Workshop Series*, 12. Kerkyra: 26-30 July 2000: 79-82.
(58) Tudela, S., 2003. *Ecofish Workshop on Sustainability Indicators in Fisheries,* Dakar, 14-16 April 2003.
(59) Vasconcellos, M and Gasalla, M. A., 2001. *Fish. Res*., 59: 279-295.
(60) Vasconcellos, M. et al., 1997. *Ecol. Model*., 100: 125-134.
(61) Vega-Cendejas, M. E. et al., 1993. *ICLARM Conf. Proc*., 26: 206-213.
(62) Zeller, D. and Freire, K., 2001. *FCRR*, 9(4): 207-212.
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